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Investigating the Effects of Free Lactation Crates on Sow and Piglet Welfare

Thesis presented by

Orla Kinane

0000-0001-8625-3073

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Head of School: Prof. Andrew Wheeler

Supervisors: Dr. Keelin O'Driscoll and Dr. Fidelma Butler

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Table of Contents

Declaration

This is to certify that the work I am submitting is my own and has not been submitted for another degree, either at University College Cork or elsewhere. All external references and sources are clearly acknowledged and identified within the contents. I have read and understood the regulations of University College Cork concerning plagiarism.

Orla Kinane

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Abstract

Farrowing crates, which are widely used in commercial pig farming, present major animal welfare problems. Sows are severely confined, being only able to stand up and lie down and not turn around for a period of five weeks around farrowing. This study compared the welfare of sows and piglets housed in two types of farrowing accommodation, free lactation pens (Free, n = 22) and conventional farrowing crate pens (Control, n = 24). Free lactation pens allowed for temporary confinement of sows at the most critical period for piglet pre-weaning mortality, from the onset of farrowing until day 4 post-farrowing. For the remainder of the time the sows were in the pens, the crate was opened wide enough for them to turn around. Sows were monitored from entry to the farrowing room (approximately day 108 of gestation) until weaning (approximately day 26 of lactation). The study examined 675 piglets, the offspring of these sows, from birth until slaughter. A range of behaviour and physical health measures were utilised to assess animal welfare and performance. Sows in the Free treatment had greater freedom of movement, as demonstrated by their use of the available space to turn around in the crates while they were open. At weaning, Free sows had significantly lower (better) locomotory scores than those which were housed in Control pens, this may be related to their improved ability to move during the 5-week treatment period. These sows also had significantly lower (better) tear stain scores around their left eyes at weaning, indicating reduced stress. Although Free sows had higher salivary cortisol concentrations overall when compared with Control sows, this is a measure that may reflect increased activity rather than higher levels of stress.

Overall, piglets from the Free treatment performed better than those from Control pens; pre-weaning Free piglets had a tendency to be heavier than those from the Control treatment, and this difference became significant post-weaning, leading to Free pigs having a mean finishing weight of 114.73kg, compared to 110.82kg for Control pigs. This increase in weight gain did not affect ADFI (average daily feed intake) and resulted in Free pigs having a significantly better FCE (feed conversion efficiency) in the weaner stage. There was a reduction in days to slaughter with free pigs reaching the 105kg target weigh in 147.56 days compared with 149.23 days for Control pigs. This is a very promising result regarding both productivity and welfare, and could result in increased profitability for producers. Prior to weaning Free piglets tended to perform less damaging behaviour than Control piglets, although this result was not significant. Most importantly, overall mortality was unaffected by treatment with total mortality of 15.95% for Free pigs and 14.42% for Control pigs (P = 0.61). Overall, the results from this study suggest that implementing a management strategy where sows have increased freedom of movement during lactation compared to traditional farrowing crates may help to improve sow and piglet welfare. Further research investigating the best length of time to confine the sow, taking litter size into consideration, would be beneficial to developing the most effective management practices for free lactation crates.

Introduction

Pig production in Ireland accounts for 8% of gross agricultural output (Veterinary Ireland, 2017). There are an estimated 290 commercial sow herds in the country with 1.6 million pigs including 149,900 breeding sows (CSO, 2017). In recent years there has been a significant improvement in pig production, with outputs at 24.8/pigs/sow/year, an increase from 21.9 in 1990 (Veterinary Ireland, 2017). In 2016, Ireland exported an estimated 235,000 tonnes of pig meat, 40% to the UK, 35% to continental Europe and the remaining 25% to international markets. Almost all pigs in Ireland are bred and reared indoors on slatted floor systems. From the week prior to farrowing up until weaning, including 28 days of lactation, sows in Ireland are generally managed in farrowing crates. However, loose farrowing pens are increasingly being used in other European countries as they are perceived to provide benefits to the sows and allow more maternal interaction with piglets (Damm, 2008).

Farrowing crates are used to improve ease of management, allow higher stocking densities, and reduce piglet mortality, particularly due to crushing (Marchant *et al.*, 2000, Wechsler and Weber, 2007). Sows in farrowing crates can stand up and lie down but cannot move around the pen. These restrictions to movement mean that the risk of piglet death due to accidental crushing is reduced (Marchant *et al.*, 2000). However, due to concerns about animal welfare, interest has been shown in developing alternatives to farrowing crates which do not confine the sow throughout this period of farrowing and lactation. Confining and restricting the sow restricts the performance of pre-farrowing and maternal behaviours (Wechsler and Weber, 2007).

The frustration of these behaviours causes stress in captive animals (Mason, 2010), and providing animals with the opportunity to display a greater range of behaviours has been shown to benefit their welfare (Boissy *et al.*, 2007). Nest building behaviour, for example, is an important part of pre-farrowing behaviour in pigs, and Herskin *et al.* (1998) found that providing environmental stimuli relevant to nesting behaviour, such as straw, affects maternal behaviour of sows in favour of higher piglet survival. Maternal behaviour has not changed in pigs through domestication, and as such the need to express such behaviours is considered extremely important (Grimberg-Henrici *et al.*, 2016). It is therefore possible that allowing sows more freedom of movement and the opportunity to display more behaviours throughout lactation may too affect maternal behaviour of sows positively. Welfare should be based on what is good for the health of the animal as well as what the animal 'wants' (Dawkins, 2006). Animals may be highly motivated to perform specific behaviours, nest building for example in pigs, which may not necessarily be 'useful' in confinement yet are extremely important to the animal. Pre-farrowing and maternal behaviours such as interacting with piglets are deeply instinctual and when frustrated can lead to stress (Dawkins, 2006). Farrowing crates prevent sows from interacting freely with their piglets and may therefore have negative effects on the sows' own welfare, as well as maternal care.

Concerns about animal welfare have meant that farming systems that confine and restrict the sow during gestation have been banned in the EU (Matheny and Leahy, 2007). Farrowing crates however, have remained in use as they are thought to play an important role in protecting piglets from crushing (Cain *et al.*, 2013). Crushing is indeed a major concern, in the first four days post farrowing especially

(Hales *et al.*, 2015), and presents both production and animal welfare problems. However, the industry must come to a solution which increases the welfare of the sow without negative effects on piglet mortality. Although several European countries (Norway, Sweden and Switzerland) have banned farrowing crates, in other countries, including Ireland, concerns around piglet mortality have meant that the farrowing crate is still widely used. This is the case even though some surveys on commercial farms have found that farrowing crates are not always better at preventing pre-weaning mortality than alternative systems (Weber *et al*., 2009, Kilbride *et al.*, 2012). Weber e*t al.*, (2009) and Kilbride *et al.*, (2012) report that mortality did not differ between crates and loose pens. However, Blackshaw*et al.* (1994), Weary *et al*., (1998) and Marchant *et al*., (2000) report greater mortality in loose pens than in crates. This discrepancy in results highlights the fact that each type of farrowing accommodation presents its own set of problems. Temporary confinement provides a compromise between farrowing crates and loose housing, and this may be an interim solution in a transition to entirely free systems, which can ensure piglet mortality remains at a minimum while increasing sow welfare.

Free lactation pens differ from free farrowing pens in that the sow can be confined for specific periods of time but provided with an increased level of freedom of movement compared to a standard farrowing crate when the risk of crushing is low. Thus, they have potential to benefit sow welfare, allowing freedom of movement, increased space allowance and permitting sows to perform more of their repertoire of behaviours. There may also be benefits to piglet welfare as an easier and more natural type of interaction with the sow is possible, and they may have better access to the udder for feeding. The use of free lactation pens could also contribute to a positive image for the pig production industry. This may be a solution which increases the welfare of the sow without having negative effects on piglet mortality or production.

The Teagasc National Pig Herd Performance Report 2017 (Teagasc, 2017) reported 10.7% piglet mortality on Irish farms, which compares very well to figures from Denmark (13.6%), Germany (14.9%), Spain (13.7%), the Netherlands (13.4%) and France (14.4%). Maintaining these low mortality levels will be important to remain competitive for the Irish pig industry. Therefore, if free lactation pens are to be used, they must be well designed and managed to ensure no negative consequences for piglet mortality. The increase in litter sizes in recent years (from 10.6 to 13.7 piglets born alive between 2000 and 2018) means that there is a concurrent increase in demand for care and nutrition from the sow toward her offspring. Maternal care can influence piglet behaviour and has consequences for milk intake and growth. The danger of piglets being crushed, particularly in the first days after birth, is high and maternal responsiveness is crucial to prevent mortality (Wischner *et al.*, 2010). In a study by Andersen *et al.*(2005) sows that did not crush any piglets showed a more protective mothering style, performed more nest building behaviour, responded sooner to piglet distress calls and nosed more toward piglets during posture changes. The use of farrowing crates as a management system may reduce the importance of maternal behaviour for piglet survival as the sow has little interaction with piglets when confined. Contrarily, when sows are kept loose the level of maternal care shown by the sow becomes a more important factor in piglet survival (Andersen, *et al.* 2005). Therefore, allowing for a greater range of maternal behaviours to be performed due to removal of extreme confinement throughout farrowing and lactation, may improve piglet survival.

Chapter 1

Literature Review

1.1 Background

Commercial pig farming employs the use of farrowing crates to manage sows during farrowing and lactation. Sows are kept confined in crates from one week before farrowing, throughout lactation until weaning, a period of five weeks; this allows ease of management for the producer and means that the greatest number of sows can be kept in the space available. However, there is growing public concern and discussion around animal welfare issues, especially regarding farmed animals (Mendl and Paul, 2004), and increased interest in banning farrowing crates (Hales *et al.*, 2013). Consumers consider farming practices which lead to poor animal welfare unacceptable (Broom, 2011) and would prefer farm animals to have freedom of movement throughout their lives (Hales *et al.*, 2013). Permanent confinement of gestating sows has been banned in Europe and this raises questions around confinement during lactation (Grimberg-Henrici *et al.*, 2018). As mentioned previously, Norway, Sweden and Switzerland have already banned farrowing crates but unfortunately, producer concerns around increased piglet mortality have led to farrowing crates remaining in use in other countries (Jarvis *et al.* 2006, Hales *et al.*, 2013), including Ireland.

The fear of piglet mortality by crushing, whereby the sow lies on a piglet resulting in fatal injury, is the main reason producers still use farrowing crates. Crushing is indeed a major concern in the first four days of life when the piglets are least mobile, with Marchant *et al.*, (2000) reporting over 50% of live-born mortality occurring during this time. This presents both a production and welfare problem. A solution must be found which maximises welfare for both the sow and piglets while maintaining production levels equal to those currently achieved in conventional farrowing crate systems. The literature reports varying results with the use of alternative farrowing systems. Herskin *et al.* (1998) reported crushing as the cause of around 50% of postnatal death in piglets when sows are kept loose in the pen. However, some surveys on commercial farms have found no benefit of using farrowing crates for overall pre-weaning mortality (Weber *et al.*, 2009, Kilbride *et al.*, 2012).

Confinement at farrowing and throughout lactation can be very stressful for the sow (King *et al*. 2018a) and can compromise welfare (Jarvis *et al.*, 2006). This problem has led to the development of alternative farrowing systems. These systems are less confined, but may however present a different set of problems, particularly regarding piglet survival (Herskin *et al.,* 1998). With the first four days post farrowing being the most critical period for crushing, confining the sow until this period has passed may increase piglet survival while also increasing sow welfare. Temporary confinement offers a compromise between the production requirements of pig farmers and the welfare needs of the animals (King *et al.* 2018b). Free lactation pens have been designed with a crate inside the pen which can be open to allow the sow freedom of movement or can be closed to confine the sow. Free pens (free farrowing and free lactation) have received more attention in recent years as a solution to the problems associated with farrowing crates (Grimberg-Henrici *et al.*, 2018). However, to promote uptake by producers it is important that alternative farrowing systems can deliver production levels comparable to those achieved at present (Hales *et al.*, 2013).

It is routine practice for sows on commercial farms to be confined for the entirety of their time in the farrowing room (Grimberg-Henrici *et al.*, 2018), a period of five weeks at a time, sows usually farrow between 4 and 7 times in their life and are then slaughtered. Crates are space and labour saving (Hales *et al.*, 2013), and are designed to reduce piglet mortality by restricting the movements of the sow and allowing the piglets a space to retreat to (Wischner *et al*. 2010). Although justified to date by the assumption that piglet mortality is reduced by farrowing crates, their use is questioned increasingly from a welfare point of view as consumers become more concerned about the welfare of farmed animals (Wechsler and Weber, 2007). However, producers remain sceptical of alternatives due to the concern of crushing, and mortality levels reported in alternative farrowing systems vary between studies. One study by Wechsler and Weber, (2007) found total mortality to be equal in crates and loose pens, with crushing accounting for more deaths in loose pens but more deaths due to other causes occurring in crates, resulting in equal mortality rates overall. This suggests that neither system is ideal and that an alternative must be found to reduce piglet mortality.

Farrowing crates are a serious animal welfare problem with permanent confinement throughout lactation leading to chronic stress in sows (Cronin *et al.*, 1991, Jarvis *et al.*, 2006). Crates inhibit the sow from performing some pre and post-farrowing behaviours. Pigs naturally display intense nest-building behaviour pre-farrowing (Wischner and Latacz-Lohmann, 2009), and are unable to perform these behaviours when confined, this leads to stress and can result in longer farrowing durations and higher numbers of piglets born dead (van Dijk *et al.*, 2005). Post-farrowing it is normal for sows to turn around to interact with and investigate their piglets, however, crates prevent sows from moving freely and interacting with piglets throughout lactation (Grimberg-Henrici *et al.*, 2016). This restriction of maternal behaviour may influence the sow-piglet relationship and could hinder the development and growth of piglets.

Alternative farrowing systems with temporary crating have been designed to provide a compromise between conventional farrowing crates and loose housed systems to provide better welfare for both sows and piglets (Goumon *et al.*, 2018, King *et al.*, 2018a). Temporary confinement allows the sow the opportunity to move freely in the pen leading to improved physical comfort and less restrictive interaction with piglets (Baxter *et al.*, 2011, Chidgey *et al.*, 2016b, Johnson and Marchant-forde, 2009). This type of farrowing management may be a practical solution which can best meet the needs of producers and their animals by maintaining current production levels and improving sow welfare through increased space allowance and freedom of movement. It is however crucially important for free lactation systems to deliver the same production results as conventional farrowing crates.

1.2 Effects on the sow

Prolonged confinement of sows influences their behaviour and physiology negatively (Jarvis *et al.*, 2006, Baxter *et al.,* 2011). Sows in farrowing crates have limited freedom of movement which limits their expression of behaviours, such as foraging and nest building. Pre-farrowing behaviour of pigs involves intense nest building, and when allowed to do so sows will remain quite active up to one day before farrowing

(Andersen *et al.,* 2005). In a farrowing crate, sows do not have access to nest building material and are forced to farrow in a place which they have not chosen themselves. Even in this barren environment, they are motivated to perform nest-building behaviour (Herskin *et al.,* 1998), which is limited to scraping the floor, biting bars and grinding teeth (Van Beirendonck *et al.*, 2014). During their time in farrowing crates, sows cannot move freely, interact with their piglets or perform maternal behaviours (Wechsler and Weber, 2007, Grimberg-Henrici *et al.* 2016). In these intensive indoor farm conditions, sows can only stand up and lie down, for periods of five weeks around farrowing (Mendl *et al.,* 2010), which is already a stressful time. This stress can cause negative effects on productivity (Held *et al.*, 2002) and may lead to longer farrowing durations (Oliviero *et al.*, 2008) and increased savaging of piglets (Jarvis *et al.*, 2004). Prolonged stress may also impact sow immunity (de Groot *et al.*, 2001), resulting in decreased longevity of sows. The use of farrowing crates is, therefore, leading to both animal welfare and economic problems on pig farms.

Confinement in a farrowing crate may impact sow physiology by eliciting a stress response. Salivary cortisol is one method used to measure stress levels in mammals (Menargues *et al.,* 2008). Cronin *et al*. (1991) and Jarvis *et al*. (2006) reported higher cortisol concentrations in crated sows when compared with loose housed sows. In contradiction to these results, Chidgey *et al.* (2016a) and Goumon *et al.* (2018) found no effect of housing on salivary cortisol concentration. However, Grimberg-Henrici *et al.* (2018) found higher cortisol levels in group-housed sows over crated sows, hypothesising this to be due to increased physical activity. From these mixed results alone, it is difficult to determine whether free accommodation reduces stress.

Goumon *et al*. (2018) used IgA concentration to assess stress levels in sows and found a positive effect of free farrowing pens, in which sows were never confined, on sow stress levels. However, this reduced level of stress did not have any effect on piglet mortality, with sows in both treatments performing equally well. Grimberg-Henrici *et al*. (2018) found group-housed sows had higher body condition after weaning than crated sows and this may be another indication of a higher level of welfare. Pedersen *et al.* (2011) found milk let-down lasted 1.8s longer in sows housed in free farrowing pens when compared with those housed in crates, this should benefit piglet growth and again suggests reduced levels of stress in loose housed sows. Stress has been linked with reduced milk production (Pedersen *et al.*, 2011) and this may be the reason sows housed in crates do not perform as well.

Sows display pre-lying behaviour as a mechanism to prevent crushing; nosing, sniffing and kneeling on front legs before descending and looking around and towards piglets before lying (Wischner *et al.*, 2010). One study found that Sows who crushed no piglets performed sniffing as part of their pre-lying behaviour more frequently and for a longer duration than sows that crushed one or more piglets. They also looked around and nosed more before lying down than sows that crushed one or more piglets (Wischner *et al.*, 2010). In farrowing crates, sows can do little more than stand up and lie down, so these behaviours which have developed to reduce crushing are inhibited.

Maternal characteristics can be transmitted behaviourally (Chidgey *et al.*, 2016b), therefore maternal behaviour of female pigs may be influenced by the maternal care experienced as piglets. Wischner *et al*. (2010) found gilts that were born and reared in loose pens had more sow-piglet interaction early in life compared with gilts reared in farrowing crates. When gilts from loose pens farrowed later in life they vocalised and touched piglets more than those reared in crates. Chidgey *et al.* (2016b) compared behaviour of sows and piglets in crates and loose pens 1-6 days post-farrowing, they found that sows in loose pens touched and investigated piglets more than those in crates. Piglets in loose pens spent less time inactive in open areas than those in crates, this shows that farrowing accommodation design can have effects on the behaviour of sows and piglets, specifically allowing more interaction between sows and piglets. Chidgey *et al.* (2016b) found that gilts born and reared in free farrowing pens had more sow-piglet interaction early in life compared with gilts reared in crates. When gilts from free farrowing pens farrowed later in life they vocalised and touched piglets more than those reared in crates. Jarvis *et al.* (2006) also found that gilts which were born and reared in free farrowing pens touched piglets more and vocalised more toward piglets. Gilts born to stressed mothers showed more abnormal maternal behaviour later in life than those born to non-stressed sows. Therefore, a move toward free crates may have positive effects on the maternal behaviour of the females born in this type of farrowing accommodation. Wischner *et al.* (2010) stated that "good maternal behaviour is the most important pre-condition for high sow productivity". In modern pig farming litter sizes are increasingly larger and demand greater care by the sow toward her offspring. Sow's behaviour can influence piglet behaviour and has consequences for milk intake and growth. With larger litters the danger of piglets being crushed is high and maternal responsiveness is crucial to prevent mortality.

Grimberg-Henrici *et al.* (2016) found loose housing systems to have a positive effect on maternal behaviour with group-housed sows having lower piglet mortality rates than conventional farrowing crate sows. Andersen *et al.* (2005) reported; sows that did not crush any piglets showed a more protective mothering style, performed more nest-building behaviour, responded sooner to piglet distress calls, nosed more toward piglets during posture changes, and were more restless when piglets were taken away. When in a group housing situation these same sows were more socially flexible, avoiding conflict to a greater extent. These findings further illustrate the importance of sow characteristics in piglet survival. On commercial farms piglets are protected from crushing by confining the sow, this strategy may reduce the importance of maternal behaviour for piglet survival as the sow has little interaction with piglets when confined. When sows are kept loose the level of maternal care shown by the sow becomes a more important factor in piglet survival.

1.3 Effects on the piglet

While more crushing may occur in loose housed systems, as previously mentioned, overall mortality is equal to that in crates (Weber *et al.,* 2007). Milk let-down has been found to last 1.8s longer in free farrowing pens (Pedersen *et al.*, 2011). It was also found that piglets had fewer teat fights and fewer piglets missed milk let-down in free pens, both advantageous for growth. As a result, piglets were heavier at 28 days after birth than those in crates. In a review by Rutherford *et al.*, (2013) higher weaning weight for piglets from free farrowing pens than those from crates was reported. These results may suggest that piglets experience a higher level of welfare in free pens when compared with conventional farrowing crates.

The main causes of piglet mortality are starvation and crushing by the sow (Edwards *et al.*, 1994), these causes are related as smaller piglets are at greater risk of crushing. In the critical four-day period after farrowing (Marchant *et al.*, 2000) it is crucial to ensure the best possible management to increase piglet survival. One study found over 50% of live-born mortality occurred in the first 4 days post farrowing and 28% of piglets born under 1.1kg did not survive to 7 days (Marchant *et al.*, 2000). With increasing litter size there is increased weight variation between piglets (Rooney *et al.*, 2019), this means that there will be more light piglets at greater risk of crushing in larger litters. Therefore, continuing to increase litter size through selective breeding may not be the best strategy to improve production. Producers aim for the greatest number of weaned piglets per sow to improve productivity however increasing the weight of pigs produced may also be very important (Pedersen *et al.*, 2011).

Farrowing accommodation affects sow behaviour and can also affect piglet behaviour. Martin *et al.* (2015) found that piglets born in alternative farrowing accommodation displayed play behaviour sooner and played more pre-weaning than those born in crates, they also found that free farrowing crate piglets displayed less damaging behaviour post-weaning. This is another sign that pigs may experience better welfare in this type of farrowing accommodation, and a positive result regarding production as less damaging behaviour will mean a reduced need for medical care of injured pigs.

Van Beirendonck *et al.* (2014) found an association between the behaviour of sows and the behaviour of their piglets. Piglets were more active when sows were standing and less active when sows were resting. Again, this illustrates the effect that environment can have on behaviour. The level of maternal care experienced in early life may influence future maternal behaviour of female offspring (Chidgey *et al.*, 2016b), as seen maternal behaviour plays an important role in piglet survival. When a piglet is crushed, survival depends on the length of time it is trapped (Weary, Lawson and Thompson, 1996) therefore the maternal responsiveness of the sow is crucially important. “The occurrence of crushed piglets is strongly related to individual differences in the protective behaviour of sows” (Wischner *et al.*, 2010). Piglets’ survival is of importance form both an economical and an animal welfare point of view, therefore the assessment of maternal behaviour is also important (Wischner *et al.*, 2010), and so a move toward a system of farrowing management which promotes better maternal behaviour will increase productivity.

The level of maternal care experienced by piglets may influence their future behaviour positively (Chidgey *et al.*, 2016b). Increased freedom of movement and increased social contact are known to affect piglet social behaviour positively (Šilerová *et al.*, 2010). Piglets given the opportunity to interact with the sow may develop a greater range of social skills than those who cannot. These social skills may enable piglets to better cope with change and stress, for example at move to the weaner stage, and could, therefore, improve productivity.

The literature reports varied mortality results in alternative farrowing crates, however. Hales *et al.* (2013) found piglet mortality was higher in pens, while others report no effect of farrowing accommodation on piglet mortality (Hales *et al.*, 2013, Moustsen *et al.*, 2013, Chidgey *et al.*, 2016a, Singh *et al.*, 2017). Mortality increases when litter size is increased and also increases with increasing parity of the sow (Blackshaw *et al.,* 1994, Weary *et al.*, 1998, Marchant *et al.*, 2000, Hales *et al.*, 2013). Goumon *et al.* (2018) found litter size influenced weight gain in piglets, with larger litters having decreased weight gain. It can be seen from these findings that various factors affect piglet mortality and production. King *et al.* (2018b) reported piglet mortality to be highest in free pens when all crates were opened once the average litter age was at 7 days, and lowest in crates opened in the afternoon. They concluded increased mortality post-opening may be reduced by opening crates individually and opening in the afternoon. Improved management of the temporary confinement system may lead to increased piglet survival.

1.4 Conclusions

From an ethical standpoint, the use of farrowing crates is questionable, consumers are becoming ever more conscious of animal welfare issues and there is increasing demand for animal welfare-friendly products (Napolitano *et al.,* 2010). It is assumed that crates decrease piglet mortality, however, this may not be the case. In Switzerland where crates were banned in 1997 mortality has been found to be influenced more by sow characteristics, such as age and parity, than by pen design (Weber *et al.*, 2009). A move away from farrowing crates may improve sow welfare through increased space allowance and freedom of movement. The use of free pens promotes increased milk production in sows and increased weight gain in piglets.

Some studies have shown that piglet mortality is not affected by farrowing accommodation (Moustsen *et al.*, 2013, Hales *et al.*, 2015, Chidgey *et al.*, 2016b, Singh *et al.*, 2017), however others (Blackshaw *et al.,* 1994, Weary *et al.*, 1998, Marchant *et al.*, 2000, Hales *et al.*, 2013) found piglet mortality to be higher in free pens than conventional farrowing crates. Although Hales *et al.* (2013) did report "a noteworthy proportion of sows in free farrowing pens delivered results comparable to those farrowing in crates". This discrepancy in results could be due to several factors including differences in sow characteristics and maternal behaviour, increased litter sizes and farm management.

Piglet mortality is affected by factors other than pen design, including genetics, management, litter size and sow behaviour (Marchant *et al.*, 2000). Hales *et al.*, (2014) found that mortality increased with increasing litter size and increasing parity of sow. Taking factors relating to the individual sow into consideration, and selecting sows for breeding based on maternal performance, may play an important role in reducing piglet mortality in alternative farrowing systems. When a piglet is crushed their survival depends on the length of time they are trapped (Weary *et al.,* 1996), therefore the maternal responsiveness of the sow is crucially important (Herskin *et al.*, 1998). Improved sow welfare could encourage good maternal behaviour, decreasing the risk of piglet mortality due to crushing.

However, there is still concern around piglet mortality, particularly during the critical period four days post-farrowing. Adoption of temporary confinement systems, rather than direct a move toward loose housing, may be the best solution at present. This type of management ensures piglets are protected at their most vulnerable stage and allows the sow greater freedom of movement which can promote improved maternal care, including increased milk production and more effective responsiveness to piglet distress calls. This improved maternal care will benefit piglet welfare and growth. It is vitally important that alternative farrowing systems can deliver the same production results as conventional farrowing crates. Therefore, more research will be needed before free lactation pens can be widely implemented (Hales *et al.*, 2013).

This study aimed to investigate the effects of temporary confinement at farrowing on the welfare, behaviour and productivity of commercially farmed pigs. As conventional farrowing crates currently predominate in the Irish pig industry, a transition to full free farrowing systems may be practially difficult; moreover, due to a lack of experience within the industry, producers may be resistant to a full switch to free farrowing because of the risk of increasing piglet mortality. Thus a system whereby sows were granted an increased level of freedom both prior to farrowing and from day 4 post-farrowing was investigated. Other than the crate, the design of the farrowing pen was extremely similar to that of a conventional pen, and only slightly larger. The aim of the experiment was to determine whether this type of system could have benefits for both pig and producer, with regard to animal welfare and performance, relative to conventional farrowing crates. In chapters 2 and 3 of this thesis the effects of free lactation pens on the behaviour, welfare and performance of both sows and piglets respectively will be discussed.

Chapter 2

Effects of Free Lactation Pens on Sow Behaviour and Welfare

2.1 Abstract

Pigs in Ireland are reared in intensive indoor systems, where sows are confined in farrowing crates for a period of five weeks each time they farrow. This practice presents major animal welfare problems, with permanent confinement banned at most other stages of production due to the negative impact on welfare. This study investigated the effects of temporary confinement at farrowing on sow welfare and aimed to determine whether this type of system could improve sow welfare through increased freedom of movement. Sows were housed in one of two farrowing accommodation treatments; conventional farrowing crates (Control) or free lactation pens (Free). Sows in the Control treatment were confined from entry to weaning, a period of five weeks. Sows in the Free treatment were temporarily confined from shortly before farrowing (approximately 24 hours) until day 4 post-partum, after which the crate was opened, and they had increased freedom of movement. Sow physical measures (weight, back-fat thickness, hoof score, locomotion score, and tear stain score) were measured at entry to the farrowing accommodation and at weaning. Salivary cortisol was measured throughout lactation. Farrowing duration, litter size, piglet mortality, and sow posture (Days 1, 3, 7 and 34 after entry) were recorded. Between entry and weaning, locomotion scores significantly increased for sows housed in the Control treatment compared with those housed in Free lactation pens ($P < 0.01$). Sows in the Free treatment were observed to use all orientations in the pen, showing that when more space is made available to them, they will choose to utilise the space, which is not possible in the highly restrictive Control system. Tear staining under the left eye was found to be less in the Free sows at weaning (Free P

= 0.05), indicating reduced stress. However, salivary cortisol concentration, was higher in Free sows overall; nevertheless, this may be due to factors other than stress, such as higher levels of activity and mental stimulation. These results suggest that free lactation pens can benefit sow welfare, increased freedom of movement throughout lactation can improve sow locomotory health, and as suggested by improved tear stain scores sow stress levels may be reduced in this type of system when compared with conventional farrowing crates.

2.2 Introduction

2.2.1 Background

The use of farrowing crates is increasingly topical in pig farming, as the general public become more aware of animal welfare issues on farms. Indeed, 94% of Europeans believe it is important to protect the welfare of farmed animals (Eurobarometer, 2016). It is recognised that farrowing crates negatively affect sow welfare as they prohibit locomotion completely and can have a negative impact on physical comfort, as evidenced by the high prevalence of shoulder sores in restricted sows (Bonde *et al.*, 2004). Specifically, farrowing crates prevent direct social contact with other sows, a choice of nest site, the opportunity to perform nest building behaviour, isolation during farrowing, the possibility for exploration, and the choice to defecate away from the resting area (Baxter *et al.,* 2011).

On the other hand, farrowing crates are attractive to producers because they can protect piglets from crushing, and they enable the use of as little space as possible, so more sows can be kept in the same room. They also enable quick, safe and easy checking of the animals by the stockperson. In countries with intensive pig production almost all sows are kept confined in farrowing crates during the entire the farrowing and lactation period (Denmark 97% of sows, Germany 90% and France 82% (Birgitte I Damm, 2008). The improved survival of piglets is the major reason for their use, and indeed a recent review and meta-analysis found a 14% increase in relative risk of piglet mortality in farrowing pens compared with crates (Glencorse *et al.,* 2019). However, although mortality due to crushing is generally found to be higher in loose farrowing systems than in crates (Hales *et al.*, 2014), other causes can be higher in farrowing crates than loose systems. Other studies have found equal piglet survival rates overall (e.g. 1.40 piglets/litter in free pens vs 1.42 piglets/litter in crates; Wechsler and Weber 2007). Protection from crushing is ever-more important with the increases in litter size that have occurred due to selection for higher sow productivity (Damm *et al*., 2003), as larger litters are associated with lower birthweights, and a higher proportion of vulnerable piglets that are at high risk of crushing, particularly if there is less space in the pen per piglet (Edwards, 2002, Milligan and Fraser, 2002). And since the first four days post farrowing are the most critical period for crushing (Marchant *et al.*, 2000), restricting the sows movement during this time may be a solution.

Animal welfare science has shown that confinement can lead to severe stress in sows (Jarvis *et al.*, 2006) and this may also have negative implications for production. Sows housed in farrowing crates are unable to perform farrowing and maternal behaviours, which can cause frustration and lead to increased farrowing durations (Oliviero *et al.*, 2008).

There is growing interest in loose housing systems across Europe. Denmark, for example, aims to house 10% of all lactating sows in loose farrowing accommodation by 2020. Although considerable research is on-going on free farrowing systems (Google scholar search identified 3,520 papers published since 2016), the UK Farm Animal Welfare Council (FAWC, 2015) concluded that satisfactory results are not yet available and commercial developments are not yet sufficiently advanced to allow recommendation of compulsory replacement of farrowing crates. (Hansen, 2018) tested ten different designs of farrowing pens for loose-housed sows and recommended there are still challenges to be resolved before implementing this type of management system on a broad scale.

Pig producers are more likely to consider implementing a system which can be proven to maintain or reduce piglet mortality when compared to current levels. Temporary confinement allows for more controlled management of sows than loose housing, while providing the same level of protection for piglets at their most vulnerable as farrowing crates. This system of management may be a compromise which can ensure current production levels are maintained while also improving sow welfare.

2.2.2 Physical measures of body condition

There are a number of physical measures which can be used to determine overall body condition. Evaluating the body condition of sows is important, as modern pig farming demands that they reach high production targets (Maes *et al.*, 2004). Sow body measurements including weight and back-fat thickness can be used to give an indication of the body condition of individuals, and whether they are in good condition to optimise piglet production. Taking these measurements before and after farrowing can provide insight into whether a novel type of farrowing accommodation used is having a negative or positive effect relative to a standard farrowing crate system. Maes *et al.* (2004) found a tendency for greater back-fat losses during lactation to predict decreased reproductive success. Minimising excessive weight and back-fat loss during lactation is essential.

The lifetime performance of commercial sows relies on longevity, which is dependent on good health. Locomotory issues account for 13% of all sow cullings, and over half of these females have not yet attained their second parity (Hartnett *et al.*, 2019). Therefore, employing a system of farrowing and lactation management which does not exacerbate locomotory problems is important for both the welfare and the productivity of sows.

Cortisol is frequently used as a biomarker of physical and psychological stress (Ruis *et al.*, 1997, Hellhammer, *et al.,* 2009). It is present in sufficient quantities in saliva such that levels can be analysed to compare levels across treatments (Proudfoot and Habing, 2015) and as saliva collection is less invasive than extracting blood, this is often used in studies of animal welfare. Indeed Goumon *et al. (2018)* collected saliva to compare cortisol levels in temporarily crated sows (when they were crated) with permanently crated sows. Contrary to what they expected, they found that cortisol levels were higher in the sows which were only temporarily crated, compared to the permanently crated sows. They suggested that the cortisol response could have been dampened in sows which were confined prior to farrowing. Thus, although levels of salivary cortisol can provide insight into sow stress levels during the peri-parturient period, they need to be interpreted with care, and in the context of other measures. Nevertheless, they and can be easily incorporated into an assessment of overall welfare when considering novel management strategies during this time, and as such are a useful tool.

Tear staining (chromodacryorrhea) refers to a dark stain below the eye, caused by porphyrin-pigmented secretion. It has been shown to be a reliable indicator of stress in rats (Mason *et al.*, 2004) and to be related to social stress and a barren environment in pigs (Telkänranta *et al.,* 2015). In that study tear staining was found to correlate with tail damage, ear damage and lack of enrichment. Interestingly they found left eye staining to correlate with tail damage scores and right eye staining to correlate with ear damage scores. Another study (Deboer *et al*. 2015) found tear staining to be greatest in pigs which were not provided with enrichment and were kept in isolation. This method has not yet been used as a welfare indicator in sows during the farrowing and lactation stage.

2.2.3 Behavioural restriction

Pre-farrowing behaviour in sows involves a phase of increased restlessness and locomotion, and a phase of nest-building (Weary *et al*., 1996). Nest building is a highly motivated sequence of behaviours (Bolhuis *et al.*, 2018), and is a behavioural need in sows regardless of the environment (Algers and Uvnäs-Moberg, 2007). Restricting the sows' ability to perform nest building behaviour has been linked to increased stress levels (Lawrence *et al.*, 1994, Jarvis *et al.*, 1997), increased farrowing duration and increased number of stillborn piglets (Oliviero *et al.*, 2008). Sow activity is extremely limited when housed in farrowing crates, as the animals are unable to turn around, and have no freedom to perform locomotory behaviour, which naturally would continue up to one day pre-farrowing, as a component of nest-building behaviour.

Allowing sows the freedom and space even to turn around and take some steps in the pen may benefit their welfare.

2.2.4 Purpose of this study

This study aimed to determine whether sow welfare could be improved by the use of free lactation crates when compared with conventional crates. Although there has been much work recently on the benefits of loose housing, uptake by producers has not followed due to concerns of piglet mortality. This study investigated a system which allows for temporary confinement, meaning both the welfare needs of the sow and the piglets when they are most vulnerable to crushing are catered to. It is hoped that this will be a more manageable change for producers to make, as the industry transitions towards loose housing. It was hypothesised that sow stress levels would be reduced through the removal of confinement, that sows would perform better as mothers (rear heavier piglets with reduced pre-weaning mortality) due to this decrease in stress, and that sows in the free lactation treatment would be more active than those in conventional farrowing crates. Salivary cortisol concentrations were expected to be higher in crated sows, and tear stain scores were also expected to be higher (indicative of increased stress levels) for sows housed in farrowing crates. No effect of housing type was expected with regard to weight or back-fat thickness.

2.3 Methods

This study was carried out in the Teagasc Moorepark Pig Development Research Facility, located in Co. Cork, Ireland. The study was approved by the Teagasc Animal Ethics Committee (TAEC192-2018).

The effects of two treatments were investigated;

Farrowing Crates (Control): The sow was confined from entry until weaning.

Free Lactation Pens (Free): The sow was temporarily confined from 24 hours before farrowing and for the first four days post farrowing (Figure 1).

Figure 1. Control and Free pens at Teagasc Pig Development Department, Moorepark, Fermoy, Cork, Ireland.

2.3.1 Treatments and experimental design

Four farrowing batches (26-30 sows/batch) were used in the experiment. From each batch, 12 sows (Large White × Landrace) which were in good general health and showed no signs of clinical lameness were selected for the study (n = 48 sows in total, 5 gilts, 19 sows in each treatment), at day 108 of gestation (day – 1 of the experiment; D-1). This was the day prior to movement from gestation housing to the farrowing pens (D0). Gestating sows were managed in a dynamic group pen which held 120 animals at any one time. The pen had two electronic sow feeders [ESF; Schauer Feeding System (Competent 6), Prambachkirchen, Austria], insulated concrete lying bays and fully slatted floors. Water was available to sows *ad libitum* from single-bite drinkers in the ESFs (electronic sow feeders) and from five drinker bowls located around the group pen. Within each batch, sows were assigned to one of six blocks on the basis of locomotion score (Mean ± SE) (1.5 ± 0.51 (1-2)), parity (2.57 ± 2.01 (1-6)), teat number (15.15 ± 1.15 (14-18)) weight (275.69 ± 39.85 (188-358)), and back-fat thickness (17.02 ± 3.63 (10-26)). One sow from each block was then randomly assigned to one of the treatments: Control or Free (i.e. six sows per treatment per batch). Treatment pens were located in one of three farrowing rooms. One room contained six Free pens. Two other rooms contained seven Control pens. Within each batch, only one of the Control rooms were used, and only the 6 Control sows within that batch were located in the room (i.e. the 7th farrowing pen was left empty).

The Control treatment consisted of conventional farrowing crates which were installed in farrowing pens measuring 184 x 250 cm (4.6 m^2) (Figure 2). The Free treatment consisted of a similar crate, located in a larger pen (212 x 261 cm, 5.5m^2). In the Control treatment the crate confined the sow and allowed for very little freedom of movement; allowing the sow to stand and lie, but not to turn or move around the pen. The crate in the Free pens allowed for the sow to be confined as before, yet the crates could also be opened to allow the sow an increased level of freedom of movement (Figure 2). When the crate was opened, the sow could freely turn around through 360°.

Farrowing rooms were artificially lit from 07.00 – 16:30. Sows were fed using a computerised feed delivery system (DryExact Pro, Big Dutchman, Vechta, Germany). Sows were fed twice daily from D0 (entry to the farrowing room) to day 14 of lactation and three times daily thereafter until weaning. The sow lactation feeding curve started at 2.9kg/d at day 0 of lactation and gradually increased to 6.3, 7.8, 8.7 and 8.2 kg/d on average, at days 7, 14, 21 and 26 of lactation, respectively. Feed troughs were checked once per day in the morning to assess sow feed intake and individual feeding curves were adjusted accordingly, by increasing or decreasing the feed allowance by 5%. Water was provided on an *ad libitum* basis to sows from a single-bite drinker in the feed trough and to suckling piglets from a bowl in the farrowing pen. In both treatments sows were provided with manipulable material in the form of thick natural fibre ropes which hung from the bars of the crates. Farm staff were present on the farm from 07.00 – 16.30 each day to assist with farrowing, provide general care to the animals, and administer medication if necessary. One sow was removed from the trial due to a shoulder lesion. Twelve piglets were removed from the trial due to health and welfare reasons, such as hunger or injury, these piglets were moved to a nurse sow and were not reintroduced to the trial.

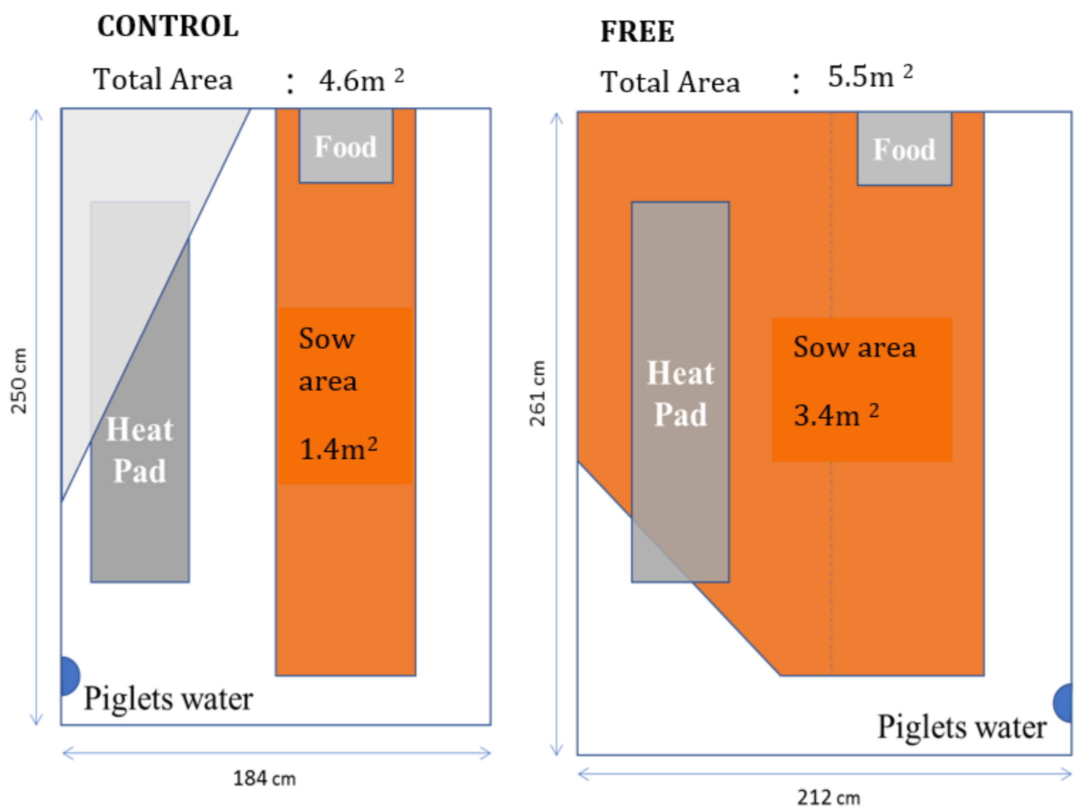

Figure 2. The Control and Free pen design. The area available to the sows in Control pens was $1.4m^2$ and in Free pens was the same while the crate was closed, and $3.4m^2$ when the crate was open. Water was available to sows *ad libitum* from a drinker located at the feed trough.

2.3.2 Animals and management

Once in the farrowing rooms, sows in the Control treatment were confined in the crate from entry until weaning, a period of five weeks. In the Free treatment, the crates were initially left open so that sows were loose and able to turn around in the pens. From the afternoon of D5, the crates were closed (16:00) to confine the sows overnight, this was to allow for habituation to the crate, then opened again each morning (08:00; Figure 3). When sows in the Free crates were observed to be producing milk (an indication that they were approximately 24 hours from farrowing) the crate remained closed in the morning. The Free sows remained confined from first sign of milk until day 4 post farrowing. After this period of confinement, the crate was reopened, and the sow was allowed freedom of movement until weaning. Farrowing was not induced.

Piglets were ear tagged within 24 hours of birth to allow for identification. Sex and birth weight were recorded within the first 24 hours. Cross fostering was carried out where necessary to ensure that there was never a greater number of piglets than functional teats. This took place within the first 48 hours, and the identities of both the birth and foster sow were recorded. Records of mortality and their cause were kept and updated daily. If crushing of a piglet was observed, an intervention to save the piglet was always attempted (i.e. attempt to move the sow to release the piglet), as is normal farm practice.

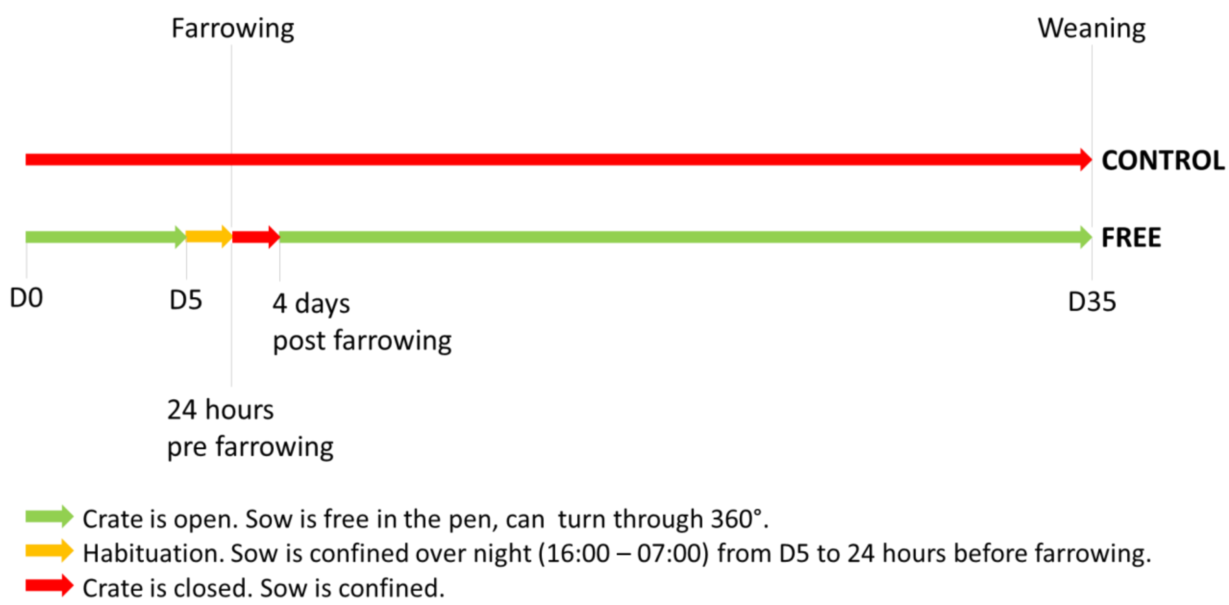

Figure 3. Timeline showing confinement in farrowing accommodation for Control and Free sows.

2.3.3 Experimental measures

2.3.3.1 Physical measures

Bodyweight and Back-Fat thickness

Sow body weight and back-fat were recorded on D-1, and again on the day of weaning, which was D35 of the experiment (26.5 ± 1 days post farrowing). Each sow was weighed using an electronic sow scales (EziWeigh 7i, O'Donovan Engineering, Co. Cork, Ireland). To calculate empty weight prior to farrowing, the following equation was used:

$$empty\ farrowing\ weight = [weight\ at\ d108 - (total\ born\ X\ 2.25)]$$

The value of 2.25 kg is an estimate of the increased weight in the gravid uterus and in mammary tissue, attributed to each pig in a litter (NRC, 2012). Back-fat thickness was measured using a digital back-fat indicator (Renco Lean-Meater, Renco Corportation, Golden Valley, Minneapolis). Two points 6.5cm from the central dorsal line and in line with the last rib were shaved, the back-fat measured, and the average of the two measurements was recorded.

Locomotion score

Sows were locomotion scored on D-1, and on the day of weaning (D35). Locomotory ability was scored while the animals walked on a solid concrete corridor for a distance of at least 10m, from the front, rear, and side of the animal. All observations were carried out by one trained observer, using the system of Hartnett *et al.,* (2019) and ranged from 0 (perfect) to 5 (unable to move) (Table 1).

Table 1: Locomotion scoring system (Hartnett *et al.*, 2019).

SCORE	DESCRIPTION
0	Even strides. Pig can accelerate and change direction rapidly.
1	Pig appears stiff. Abnormal stride, which is not easily identified. Movements no longer fluid but pig still able to accelerate and change direction rapidly. Caudal swagger evident.
2	Uneven stride. Sensitivity while walking detected on at least one limb. Pig able to accelerate and change direction. Caudal swagger evident.
3	Uneven stride, with a stagger. Minimum weight bearing on affected limb. Slow to move. Obviously lame.
4	Pig may not place affected limb on floor.
5	Does not move.

Hoof score

Hoof score was recorded for all sows on D1 (i.e. the first day in the farrowing rooms) and on the day of weaning (D35). Hind hooves were scored. Scoring was carried out when sows were lying down, and hooves were visible to the observer. At weaning, hoof scores were recorded by raising the sows 0.75m above the ground using a hydraulic chute (FeetFirst Sow Chute, Zinpro Performance Minerals, Eden Prairie, Minnesota, USA). The medial and lateral toes, medial and lateral dew claws, sole and heels of both hind feet were inspected and severity of the following lesions was scored; heel erosion, heel-sole separation, white line separation, dew claw length, dew claw cracks, toe length and vertical and horizontal toe cracks. The scoring system was a modified version of the FeetFirst claw lesion scoring guide from Zinpro Corporation (Hartnett *et al.*, 2019). Details of the scoring system are described in Table 2.

Table 2: Hoof lesion scoring, adapted by Hartnett *et al.* (2019) from the FeetFirst claw lesion scoring guide (Zinpro Corp., Eden Prairie, MN).

Hoof lesion category	**Score**				
	0	**1**	**2**	**3**	**4**
Heel overgrowth and erosion	Normal	Slight overgrowth and/or erosion in soft heel tissue	Numerous cracks with obvious overgrowth and erosion	Large amount of erosion and overgrowth with cracks	Extremely overgrown/eroded
Heel-sole crack	Normal	Separation forming	Slight separation at the juncture	Long separation at the juncture	Long and deep separation at juncture
White line damage	Normal	White line forming	Shallow and/or short separation along white line	Long separation along white line	Long and deep separation along white line
Dew claw length	Normal	Slightly longer than normal	Significantly longer than normal	One or more claws much longer than normal and/or torn	NA

Table 2 continued: Hoof lesion scoring, adapted by Hartnett *et al.* (2019) from the FeetFirst claw lesion scoring guide (Zinpro Corp., Eden Prairie, MN).

Dew claw cracks	Normal	Short crack(s)	Long but shallow crack(s) in the dew claw wall	Multiple/deep crack(s) in the dew claw wall and/or partially or completely missing	
Toe length	Normal	One or more toes slightly longer than normal	One or more toes significantly longer than normal	One or more toes much longer than normal and/or the toes are torn and/or partially or completely missing	NA
Cracked wall Horizontal	Normal	Haemorrhage evident, short/shallow horizontal crack in toe wall	Long but shallow horizontal crack in toe wall	Multiple or deep horizontal crack(s) in toe wall	NA
Cracked wall Vertical	Normal	Short/shallow vertical crack in the wall	Long but shallow vertical crack in the wall	Multiple or deep vertical crack(s) in the wall	NA

Tear stain score

Sow tear stain scores were recorded on D0 and on the day of weaning, according to the DeBoer-Marchant-Forde scale (Deboer *et al.*, 2015). Excess dirt was initially removed gently from the eye area using warm water to provide for a standardised baseline as much as possible, and thus allow for more accurate measurement of staining throughout the time in the farrowing pens. Each eye was scored separately according to the following scoring system: 0 = no visible stains, 1 = barely detectable stains not extending below eyelid, 2 = visible stain < 50% in ratio to the eye, 3 = visible stain 50-100% in ratio to the eyes, 4 = visible stain > 100% in ratio to the eye but not extending below the mouth line, 5 = visible stain extending below the mouth line (Figure 4; Deboer *et al.,* 2015).

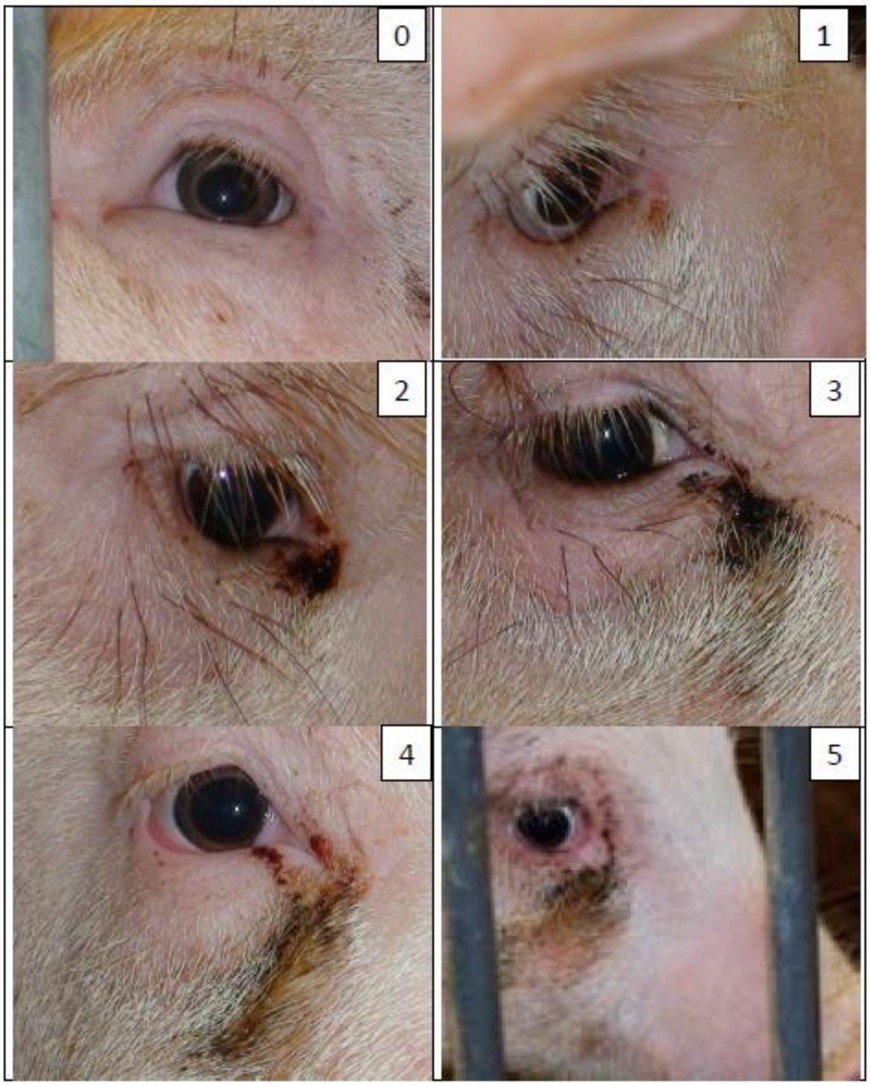

Figure 4: Tear stain scoring from DeBoer-Marchant-Forde 0 – 5 descriptive scale (Deboer *et al.*, 2015).

Salivary cortisol

One saliva sample was collected from each sow, between 09:00 and 10:00 on each of ten collection days. The first was collected on D0, when sows were waiting in the collection area outside the group gestation pen. Subsequent samples were collected on days 2, 3, 5 and 6 after entry to the farrowing rooms, on days 5, 7, 14 and 21 after farrowing, and on the day of weaning. On days 2, 3 and 5, sows in the Free treatment were not confined in the crates. On the morning of day 6, they had been confined overnight for the first time. On day 5 post-farrowing, the crate had been opened overnight for the first time since farrowing and remained so for the rest of lactation.

Saliva samples were collected by allowing the sow to chew on a cotton bud (Salivette, Sarstedt, Wexford, Ireland) for 30 to 60 seconds until it was thoroughly moistened. Cotton buds were always taken voluntarily by the sows, the experimenter stood outside the pen when sows were housed in farrowing accommodations. Samples were placed in plastic tubes, stored at 8 °C for no longer than 5 hours, then centrifuged at 1500rpm for 25 minutes and stored at – 20°C until analysis.

At analysis samples were defrosted, centrifuged, and analysed in duplicate using a commercially available salivary cortisol assay kit (Expanded range high sensitivity salivary cortisol enzyme immunoassay kit, Salimetrics Europe Ltd., Suffolk, UK), according to the manufacturer's procedure. Cortisol was detected at a minimum concentration of <0.003µg/dl. The inter-assay CV (n=16 plates) was 32%, and intra-assay CV (n=443 samples) was 8.83%.

2.3.3.2 Behaviour measures

Farrowing duration

All farrowing pens were recorded continuously by video cameras (QVIS HDAP400 CCTV cameras and a Pioneer-16 digital recorder case, CCTV Ireland, Kildare, Ireland) from entry to farrowing room until all sows had finished farrowing, and on D34 of the experiment (day 25.5 ± 1 of lactation). Farrowing duration was extracted from the videos by observing each sow continuously from birth of the first piglet until birth of the last. From this, the total farrowing duration, and the interval between the birth of each individual piglet was recorded.

Sow posture and orientation

Video footage from D1, D3, D7, and D34 (day 25.5 ± 1 of lactation) were observed. On D1 and D3 sows in the Free treatment were loose in the pen since entry. On D7, sows had been confined overnight for two nights. Videos were observed using scan sampling at 5-minute intervals between 11:00 and 17:00 (73 samples/sow/day). At each time point, sow orientation (1 to 12 as per the position of numbers on an analogue clock face; position 12 was oriented with the head directly facing the feeder) was recorded for Free sows (sows in the Control treatment were always oriented towards the feeder). The number of piglets which were touching the sow was also recorded on the last observation day (day 25.5 ± 1 of lactation).

Response to separation from piglets

The responsiveness of the sow to her piglets was estimated by carrying out a separation and return test, on day 21 – 22 of lactation. Piglets were removed from the pen for 2 hours to ensure that they had missed approximately 2 nursing bouts. All sows were encouraged into a standing position immediately prior to the piglets being returned to the pen. The time that it took the sow to lie down and then to nurse the piglets was recorded.

2.3.4 Statistical Analysis

Statistical analysis was carried out using SAS (v 9.4, SAS Institute Inc., 1989), and the sow was considered the experimental unit. All data were tested for normality prior to analysis by examination of histograms and normal distribution plots using the univariate procedure.

When linear models were used, residuals were inspected after analysis to confirm normality. Model fit was determined by choosing models with the minimum finite-sample corrected Akaike Information Criteria (AIC). Degrees of freedom were estimated using Kenwood-Rogers adjustment. Results were deemed statistically significant when α level was below 0.05, and a tendency was considered when α level was between 0.05 and 0.1. Either the Tukey-Kramer or Bonferroni adjustments were used for multiple comparisons where least squares means (LS means) were determined and P-values were adjusted. Data are presented as LS means and standard errors.

Physical measures

Sow weight, back-fat and feed intake during lactation were analysed using general linear models, with treatment, sow parity and replicate included as fixed effects. Parity was classified as either first parity, or greater than first parity, in this model and all others. Empty weight at farrowing was considered a covariate for weaning weight, and for the other measures, values recorded at assignment to treatment were considered covariates. Feed intake was compared on the basis of total intake, and average intake per day.

The Mann-Whitney test (Proc Npar1Way) was used to compare locomotion scores, at weaning, as on entry to the farrowing rooms half of the animals in each treatment had a score of 1, and half had a score of 2.

The total hoof score (i.e. sum of the individual measures for all four claws) was analysed using a general linear model. Fixed effects were as before, with the addition of inspection (i.e. entry to the farrowing crate, and weaning), and the interaction between inspection and treatment. Inspection was considered a repeated effect, and a compound symmetry covariance structure was specified. For analysis of the individual hoof scores, a generalised linear model was used (Proc Genmod), with the same fixed and repeated effects as before. A multinomial distribution was specified, with a cumulative logistic link statement.

The Mann-Whitney test (Proc Npar1Way) was used to compare tear stains for both the left and right eyes at entry to the farrowing rooms and at weaning.

Salivary cortisol was measured using a general linear model, with the same fixed effects as before (treatment, parity, collection day, and replicate). The initial sample was used as a covariate. Collection day was considered a repeated effect, with an autoregressive covariance structure. The EIA plate was included as a random effect. Due to the extremely large number of multiple comparisons, a post-hoc Bonferroni test for multiple comparisons was applied to only the raw P-values calculated between treatments on each sampling day.

Behaviour

Farrowing duration and the interval between birth time of piglets were both analysed using a general linear model, with the same fixed effects as before. For the birth interval, the birth order of the piglet was also included, and this was also considered a repeated effect, with an autoregressive covariance structure. Total number born was also included as a covariate as this could not be controlled for in the experimental design. The interval between piglets was log transformed so that residuals approached normality.

The percentage of time that sows spent in each posture (stand, sit, lie on the belly, lie on the left side, lie on the right side, and total lying on side) was calculated across all the observations on each recording day and analysed using a general linear model as before. Recording day was included as a repeated measure with an autoregressive covariance structure. The percentage of piglets that were in contact with the sow was analysed using a similar model, but without the repeated effect of day, and the percentage observations that sows were observed nursing analysed using the Mann-Whitney test.

Only sows in the Free treatment were used in the analysis of orientation in pen, as the sows in the crate treatment were always restricted so that their heads were in the direction of the feed trough. The percentage of recordings that sows spent with their head pointing towards each direction was calculated for each recording day and analysed separately using a general linear model as before. Both direction and day were considered repeated effects, and as such a direct product autoregressive correlation structure was used. The number of transitions between positions per hour was also calculated and analysed using a similar model, without repeated effects.

The time to lie, and time to nurse piglets after the separation and return test were analysed using a general linear model. Only data from the first three replicates were available for this analysis.

2.4 Results

2.4.1 Physical measures

Weight, back-fat thickness and feed intake

There was no effect of treatment on any aspect of live-weight, back-fat depth measurement, or feed intake (Table 3).

Table 3. Effect of management in a standard farrowing crate or a free lactation crate on live-weight, back-fat depth, and body-condition loss during lactation. Mean ± SE.

	Control	Free	P- value
Live weight (kg)			
Empty farrowing weight	232.39 ± 6.43	266.96 ± 6.56	0.50
Weaning	246.37 ± 3.74	241.44 ± 3.93	0.29
Back-fat depth (mm)			
Entry	16.93 ± 0.77	17.10 ± 0.73	
Weaning	14.42 ± 0.42	14.40 ± 4.42	0.97
Lactation live weight loss (kg)			
Entry to weaning	-25.15 ± 4.18	-27.26 ± 4.27	0.69
Farrowing to weaning	-34.52 ± 1.94	-33.67 ± 1.98	0.72
Lactation back-fat loss (mm)			
Entry to weaning	2.21 ± 0.58	2.59 ± 0.59	0.60
Feed intake (kg)			
Total intake	170.8 ± 1.8	169.1 ± 1.9	0.44
Average daily intake	6.86 ± 0.07	6.77 ± 0.07	0.25

Locomotion score

At entry to the farrowing rooms, 50% of sows in both treatments had a score of 1, and 50% had a score of 2. Both the locomotion score at weaning, and the difference in locomotion score between entry and weaning, was affected by treatment ($P < 0.01$ for both), with scores being greater for Control sows than Free. The percentage of sows in each treatment that had a score of 1, 2, 3 and 4 at weaning are shown in figure 5.

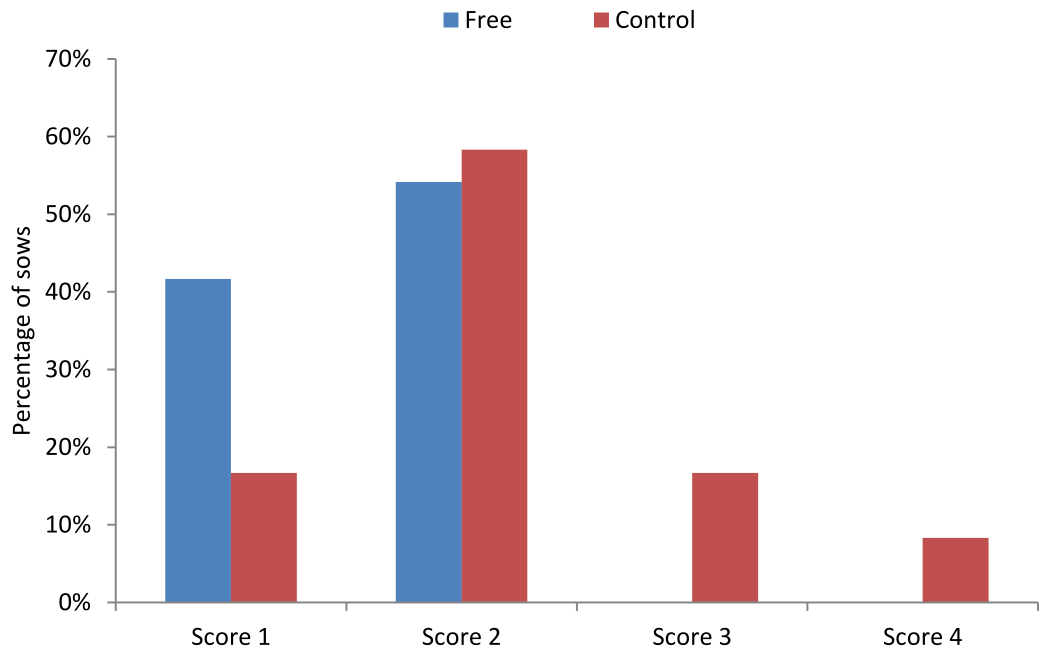

Figure 5. The mean percentage of sows that had locomotion scores 1, 2, 3 and 4 at weaning. No sows housed in the free lactation treatment had a score higher than 2 at weaning, while 17% of crated sows scored 3, and 8% scored 4 at weaning.

Hoof score

Treatment had no effect on total hoof score (i.e. the sum of the individual scores for each disorder; P = 0.69), but there was an effect of inspection (P < 0.001), with sows having higher (worse) scores at exit (41.57 ± 1.19) than when they entered the farrowing room (36.29 ± 1.19). The difference tended towards significant for sows in the Control treatment (P = 0.07) and was significant for Free treatment sows (P < 0.01) (Figure 6). However, there was no interaction between examination time (entry and exit to the farrowing room) and treatment (P = 0.43). There was also an effect of parity (P < 0.05), with the hoof score of sows that were farrowing for the first time being lower (i.e. better; 36.52 ± 1.94) than sows from all other parities (41.34 ± 0.93).

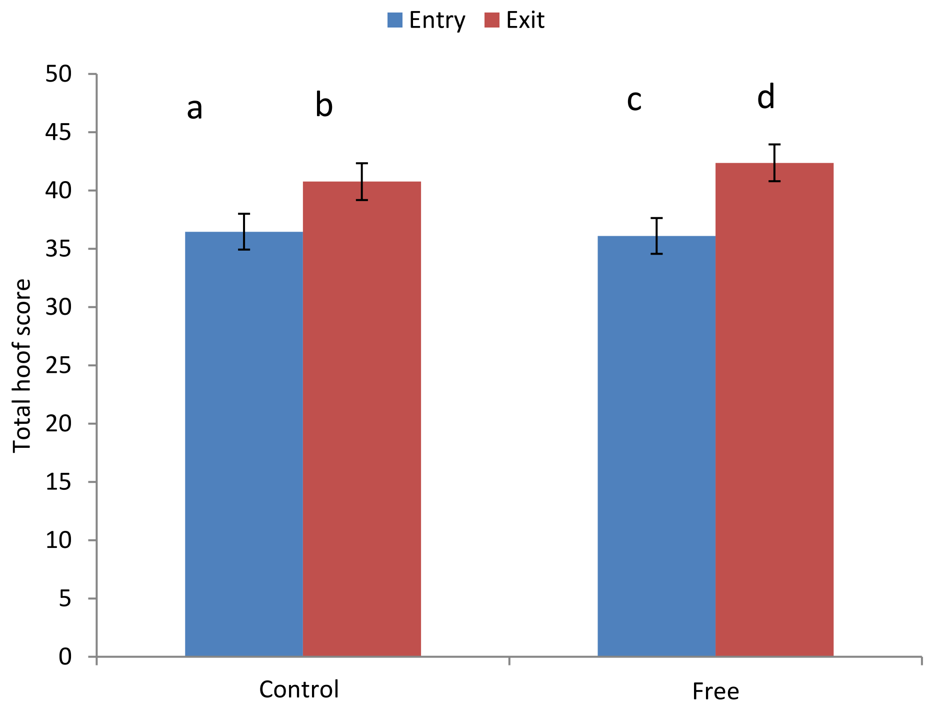

Figure 6. Mean ± SE total hoof scores for sows in either the Control or Free treatment. a, b indicate a significant difference at P < 0.1, c, d at P < 0.01.

With regard to the individual disorders which were investigated (heel overgrowth and erosion, heel-sole crack, white line damage, dew claw length, dew claw cracks, vertical cracks, horizontal cracks and toe length) there was no effect of treatment on any of the disorders, or interaction between treatment and inspection time. There was, however, a tendency for higher heel erosion and heel-sole crack scores in Free sows compared with Control (table 4).

Table 4. Hoof disorder scores for sows in the Control and Free treatments. Data are presented as medians and inter-quartile ranges.

	Control	**Free**	**P - value**
Heel overgrowth and erosion	8 (6.25 -9)	8 (6 – 10)	0.09
Heel-sole crack	8 (6 – 9.75)	9 (6 -10)	0.10
White line damage	7 (5 – 8)	6 (5 – 8)	0.97
Dew claw length	6 (4 – 7)	5 (4 – 6)	0.12
Dew claw cracks	6 (3.25 – 8)	5 (3 – 7)	0.56
Vertical cracks	2 (1 – 4)	2 (1 – 3)	0.40
Horizontal cracks	1.5 (1 – 3)	2 (1 – 3)	0.40
Toe length	2 (2 -2.75)	2 (2 – 2)	0.78

Tear stain score

At entry to the farrowing rooms there was no difference in tear stain scores between treatments for either the left eye, or the right eye (Table 5). However, by the end of the experiment, although there was yet no effect of treatment on tear stain score for the right eye, sows in the Free treatment had lower tear stain scores around the left eye than those in the Control.

Table 5. Tear stain scores for both the left and right eyes for sows in both treatments, at entry to the farrowing rooms and at weaning. Data are presented as medians and interquartile ranges

	Control	Free	P- value
Left Eye			
Entry	2 (1 -3)	2 (1 – 3)	0.38
Weaning	2 (2 – 3)	2 (1 – 2)	0.05
Right Eye			
Entry	2 (1.5 – 3)	2 (1 – 3)	0.50
Weaning	2 (2 – 3)	2 (1 – 3)	0.29

Salivary cortisol

Salivary cortisol tended to be higher in Free sows (0.341 ± 0.023 µg/dl) than Control (0.279 ± 0.023 µg/dl; $P = 0.062$). There also tended to be an interaction between treatment and sampling day ($P = 0.09$; Figure 7). On the second day after entry to the farrowing pens, sows in the Free treatment had higher cortisol levels than Control ($P < 0.05$), and they tended to have higher levels on the day after the crates were opened post-farrowing ($P = 0.09$).

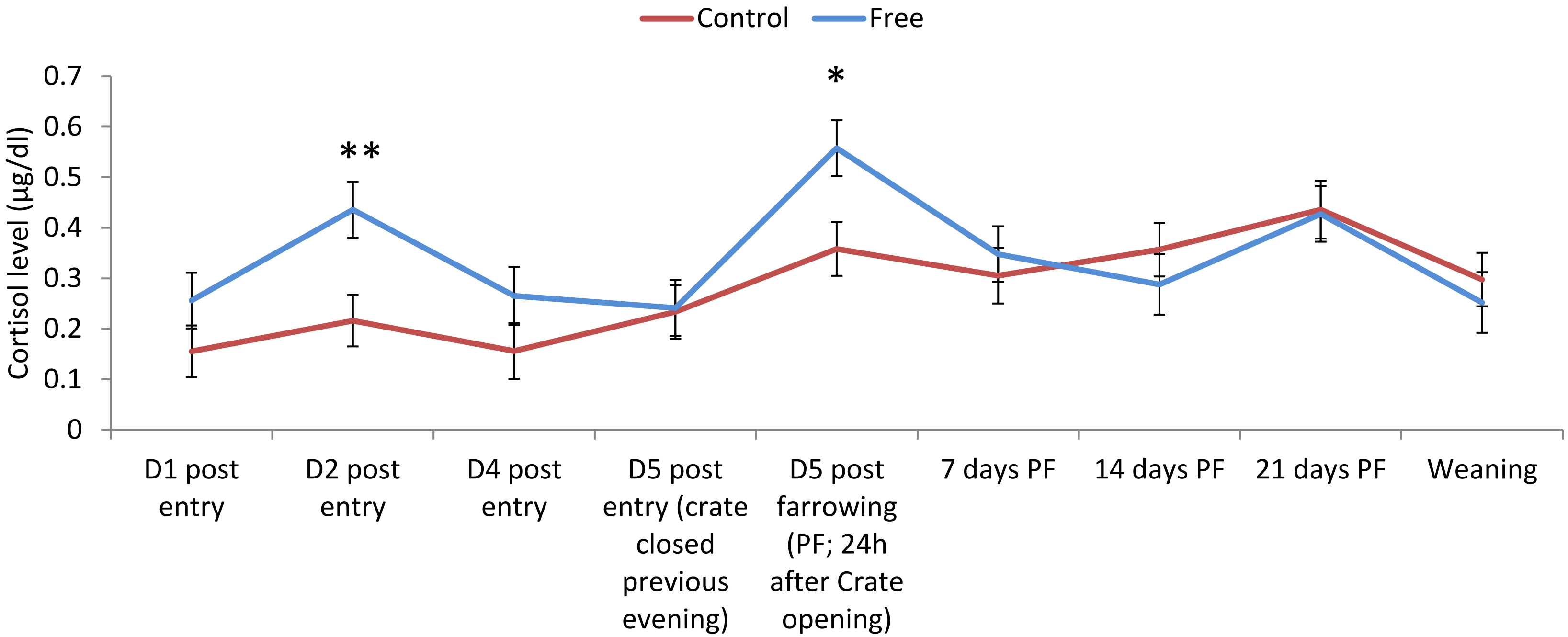

Figure 7. Mean ± SE salivary cortisol levels of sows in the Control (standard farrowing crate) or Free (sows enclosed in a crate from the onset of milk let-down until day four post farrowing) treatments throughout the experiment. Crates were opened three days post farrowing (PF). * indicates a tendency for a difference between treatments ($P < 0.1 > 0.05$), and ** indicates a significant difference ($P < 0.05$) on that recording day.

2.4.2 Behaviour

Farrowing duration

There was no effect of treatment on farrowing duration; in total, Free sows took 07:43:49 ± 01:16:55 to farrow, whereas Control sows took 07:45:42 ± 01:15:25 to farrow. Neither was there a difference in farrowing interval (Free = 00:07:14, Control = 00:08:47, (back transformed Least Squares means)).

Sow posture

There was no effect of treatment on the proportion of time that sows spent standing ($P = 0.70$) or sitting ($P = 0.45$; Figure 8). Overall, Free sows tended to spend more time lying on their bellies (Figure 8; $P = 0.07$), and Control sows spent more time lying laterally (Figure 7; $P < 0.05$). The amount of time spent lying laterally was also investigated, as a percentage of the total time spent lying. Here again, sows in the Control treatment spent a higher proportion of lying time on their side (76.32 ± 0.04%), than sows in the Free pens (65.08 ± 0.04%; $P < 0.05$).

Although there was no interaction between the time spent lying on the belly or laterally and recording day, numerically the time spent lying on the belly increased across time for sows in the Control treatment, but not in the Free treatment (Figure 9A), whereas time spent lying laterally decreased for Control sows but not for Free.

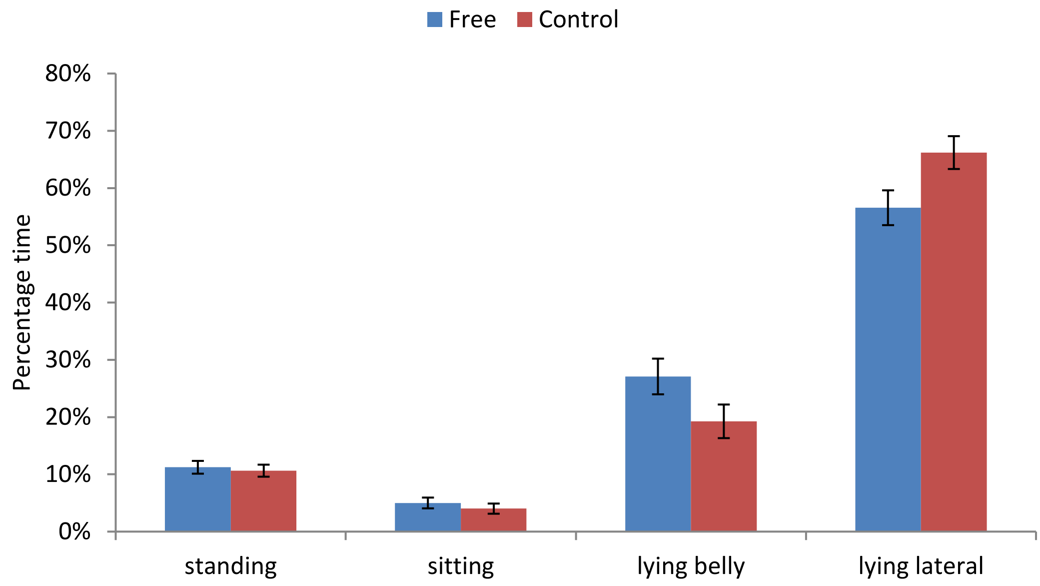

Figure 8. The mean ± SE percentage time sows in either standard crates (Control) or free lactation (Free) pens spent in various postures before and during lactation. Data were collected on D1, D3, D7 and D34 relative to entry to the farrowing pens.

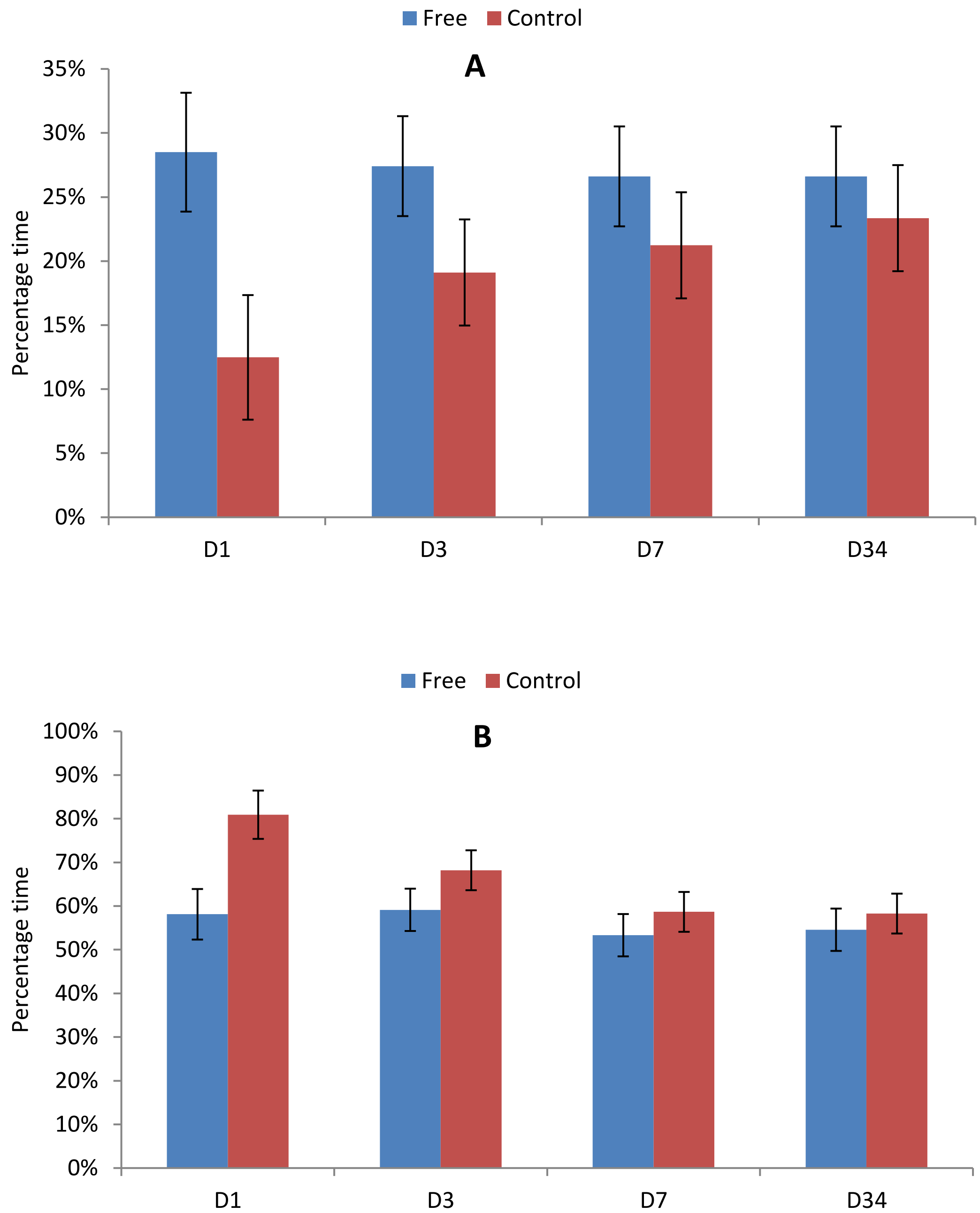

Figure 9. Mean ± SE proportion of time spent lying on belly (A) and lying laterally (B) on each recording day (D1, D3, D7 and D34 (approximately day 25 of lactation) after entry) for sows housed in free lactation pens and conventional farrowing crates. On D1, D3, and D34 Free sows were unconfined, and on D7 they were confined at night but not during the day. The Crate sows were confined in farrowing crates for the duration of the study.

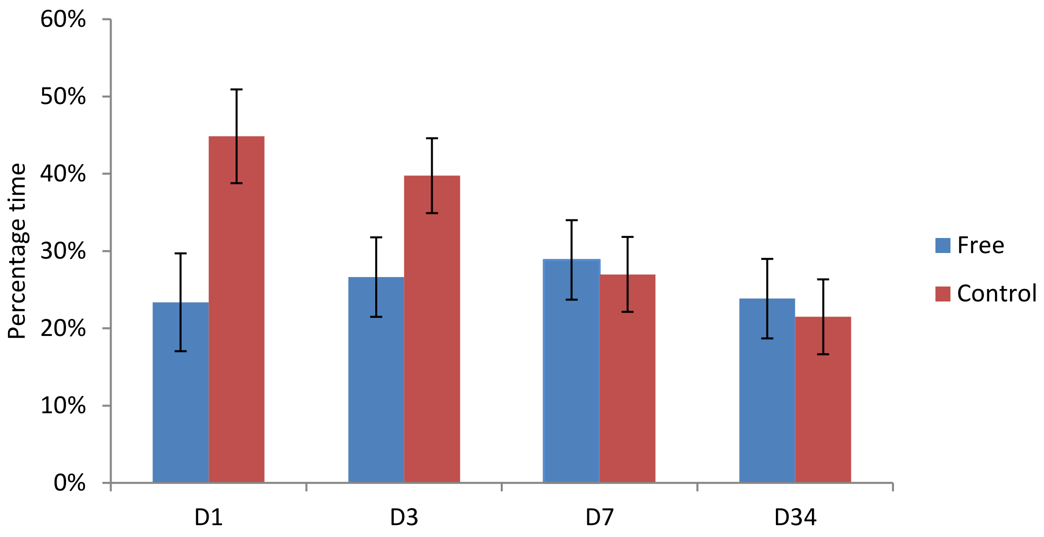

Figure 10. Mean ± SE proportion of time spent lying on the left, relative to the total time lying, on each recording day (D1, D3, D7 and D34 (approximately day 25 of lactation) after entry) for sows in the Free and Control treatments.

It was found that sows in the Free treatment tended to spend less time lying on the left side than sows in the Control treatment (P = 0.01). Although there was no interaction between treatment and time, it appeared that this was driven by a higher proportion of lying time spent on the left side in Control sows on D1 and D3, which corresponds to the initial time spent crated after entry to the farrowing pens. During these two days, Free sows were not confined in the farrowing crate.

Orientation in the pen

The orientation of each sow in the Free treatment was recorded as though the sows head pointed towards the numbers on a clock face (i.e. 12 representing the sows head oriented directly forward in the pen toward the trough, and 6 representing the sows head pointed towards the back wall of the pen). Overall, sows spent the highest proportion of observations oriented directly towards the front of the pen (40.4 ± 2.2%), indeed significantly more than in any other orientation ($P < 0.001$ for all comparisons). This was followed by having their head oriented towards position '1' on a clock face, then directly towards the rear of the pen, position '6' (21.2 ± 2.2%, and 15.0 ± 2.2%, respectively).

There was an interaction between day, and the orientation of the sows ($P = 0.001$), and the percentage time that sows spent oriented towards each number on a clock face, on each day, can be seen in Figure 11. The only significant difference between the proportion of time spent oriented in any direction between days, was between the time spent oriented directly towards the feed trough on D3 and D7 ($P < 0.05$) and on D7 and D34 ($P < 0.001$). The highest percentage was on D7, which represents a day prior to farrowing when sows had been confined in the crates the previous night, and the lowest percentage was on D34, when sows were approximately 3 weeks into lactation.

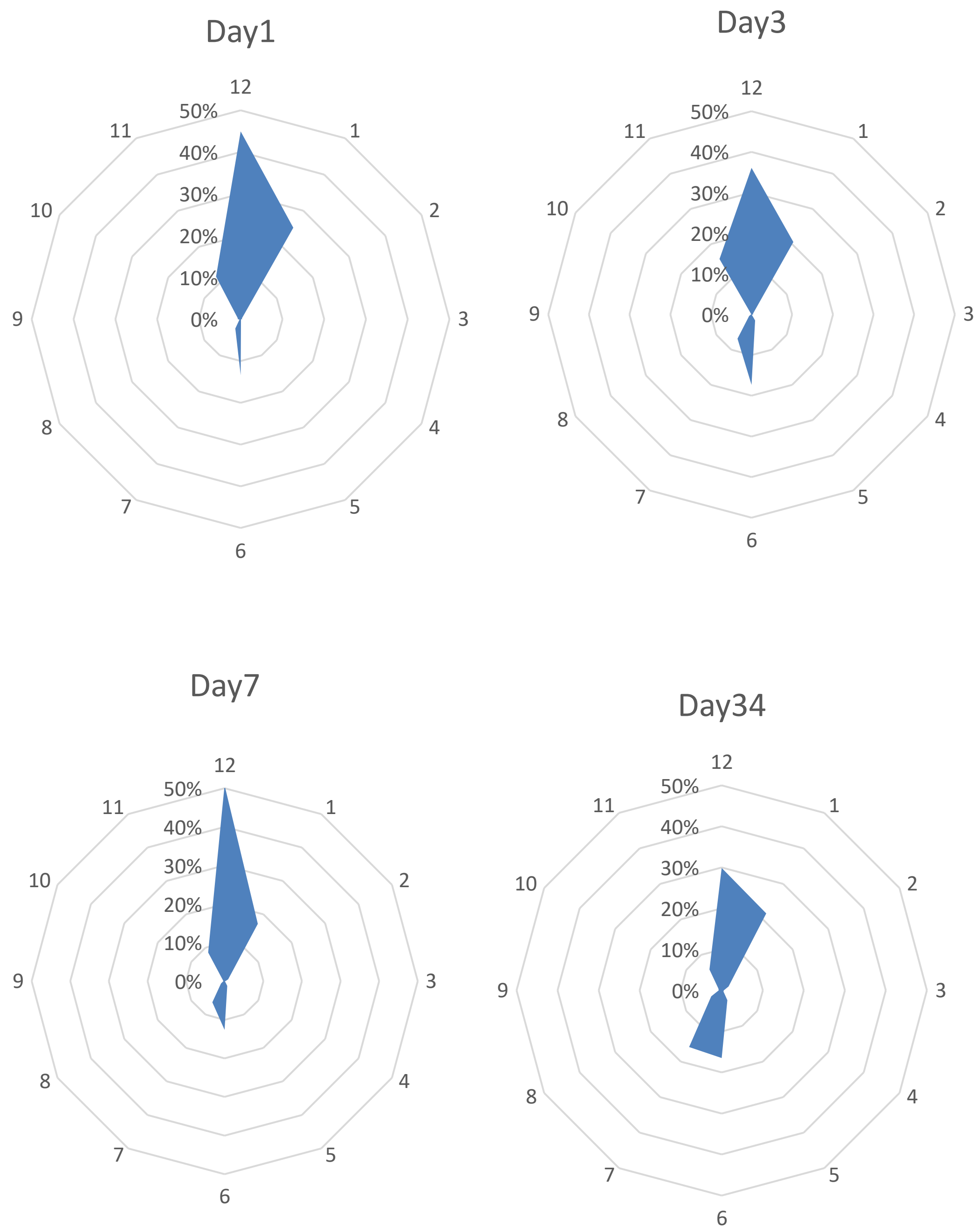

Figure 11. Sow orientation in Free pens on D1, D3, D7 and D34 (approximately day 25 of lactation) after entry. Position 12 represents the feed trough, and position 6 the rear wall of the pen. An increasing distance between the data-point representing each position from the centre point of each graph indicates an increasing proportion of observations with the head oriented towards this position.

The number of times each sow changed orientation increased as the experiment progressed ($P < 0.05$; Figure 13), and indeed there was a significant difference in the number of transitions between D1 and D34 ($P < 0.05$).

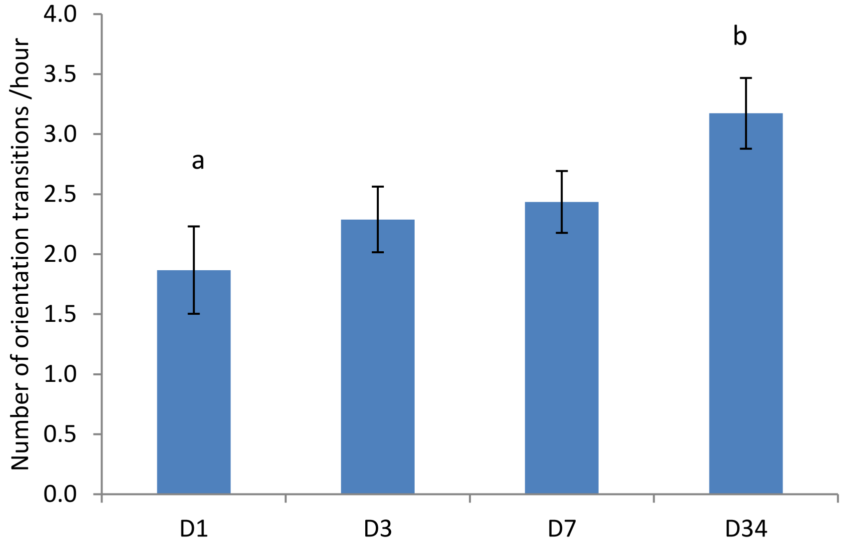

Figure 12. The mean ± SE number of sow orientation changes per hour on D1 D3 D7 and D34. a, b indicate a significant difference at $P < 0.01$.

Proximity of piglets

The percentage of piglets in contact with the sow, recorded at 5-minute intervals between 10:00 and 16:55 inclusive on D1, D3, D7 and D34, was not affected by treatment (Control = 46.5 ± 3.0%, Free = 46.1 ± 3.1%; $P = 0.88$). However, there was an effect of hour of the day ($P < 0.05$), and an interaction between treatment and hour of the day ($P = 0.01$; Figure 13). In general, piglets in the Free treatment were observed in contact with the sow more often in the morning and late afternoon, whereas in the Control treatment there was a peak in early afternoon. Although there was no significant difference at any time point, more piglets in the Control treatment tended to be in contact with the sow in the hour leading up to 14:00 than in the Free treatment.

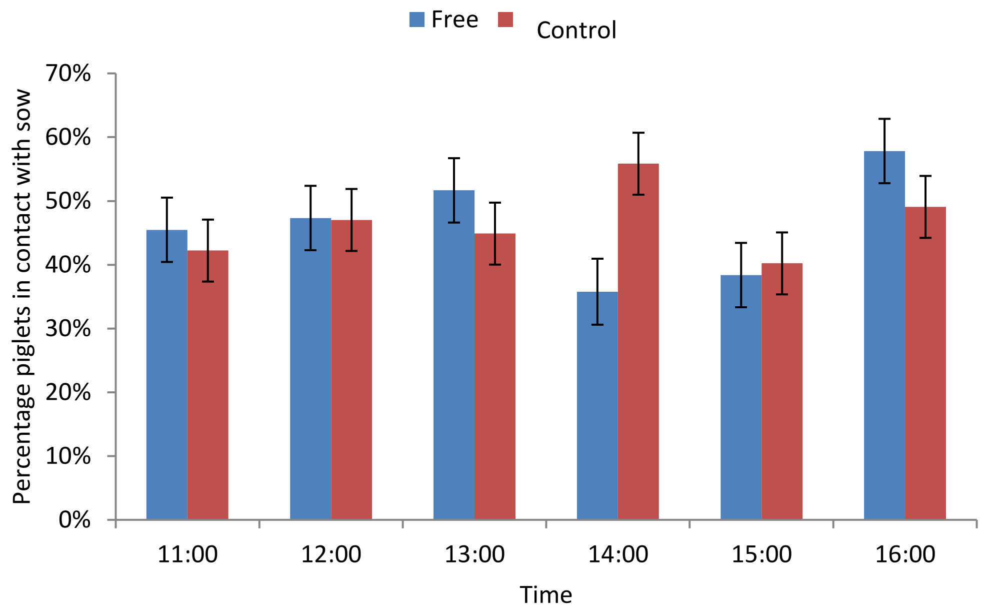

Figure 13. Mean ± SE percentage of piglets in contact with sow by hour in free lactation and farrowing crate treatments.

Response to separation from piglets

There was no effect of treatment on either the time it took sows to lie down after being separated from their piglets, or the time it took to nurse them (Figure 14).

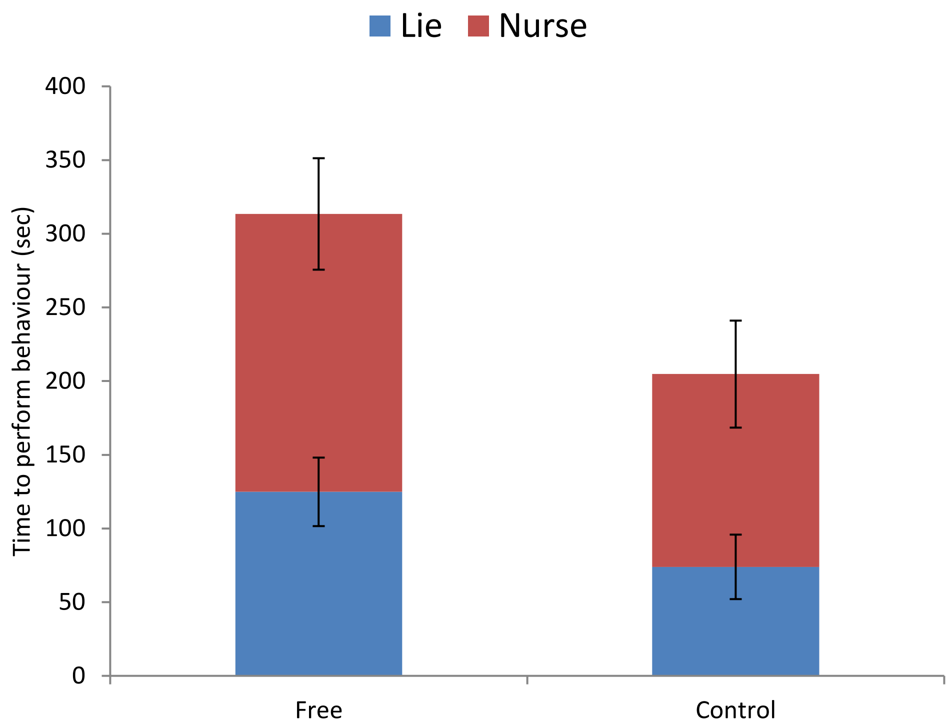

Figure 14. Mean ± SE time taken for sows in the Free and Control treatment to lie down and to nurse when piglets were reintroduced after 2 hour separation.

2.5 Discussion

A number of physical and behavioural measures were recorded over the course of the study period in order to assess sow body condition and welfare. Sows housed in free lactation pens had improved locomotory scores at weaning when compared with Control sows. Tear stain scores of the left eye were lower in Free sows at weaning, however salivary cortisol concentrations were higher. There was no effect of treatment on farrowing duration, or on weight or backfat. Sows in free lactation pens made use of the greater freedom of movement by using all orientations in the pen.

2.5.1 Physical Measures

The physical condition of the sow is extremely important not just for welfare, but with regard to performance. Sows that lose excessive body condition during lactation have impaired reproductive performance subsequently (Thaker and Bilkei, 2005), and thus the finding that there was no difference between treatments is important from the perspective of economic sustainability of both systems. These measures can also give an indication of overall general health, and thus again, it is positive to see no difference in weight loss or back-fat thickness loss in the sows in the free lactation pens relative to the standard crates. This was the case, even though sows in the Free pens appeared to be more active, as they were able to orient around the pen. Thus, any impact of increased activity did not have a negative impact on body condition.

At the same time, there was a negative impact on hoof health when sows were managed in the free lactation pens, compared with standard crates. Although hoof damage scores increased in both treatments between entry and exit, the increase was only significant for sows in the free lactation pens. Hoof damage in sows is generally a consequence of mechanical damage, and the ability to move more freely and often in the free lactation system could thus have been an underlying cause. The aspects of hoof heath which appeared most affected were erosion to the heel, and damage to the join between the heel and the sole, both of which can be associated with wear and tear of the tissue of the foot. Nevertheless, although the level of hoof damage was higher in sows in the free lactation pens, sows in this system had better locomotory ability at weaning than sows in the standard crates. This could indicate that maintaining some level of movement throughout lactation prevents sows from becoming stiff in their limbs.

On exit from the farrowing rooms sows from the free lactation accommodation had lower tear stain scores for the left eye than those housed in conventional farrowing crates. Tear stain score (chromodacryorrhea) is a measure of stress commonly used in laboratory rats and more recently in pigs (Larson *et al.*, 2019), Telkänranta *et al.* (2015) found tear staining to correlate with ear and tail damage, Deboer *et al.* (2015) found that isolation and lack of enrichment resulted in higher tear stain scores, and Chou *et al.* (2018) also found a correlation between tail damage and tear stain scores. It is therefore possible that the sows which were housed in free lactation pens and showed lower levels of tear staining of the left eye at weaning, experienced less stress throughout the period of farrowing and lactation then those housed in conventional farrowing crates.

Although it was anticipated that sows in the free lactation treatment would experience less stress, and thus have lower salivary cortisol levels, than those in the standard farrowing crates, the opposite was found; overall, there was a tendency for a higher cortisol level in sows housed in the free lactation pens than those housed in conventional farrowing crates. Indeed this was the case particularly on days when the opposite response was expected; on the second day after movement to the farrowing pens (i.e. sows in the conventional system had at this point been confined for 48 hours) and on the day after the crate had been opened post-farrowing (i.e. a day when the sows in the free lactation system had experienced freedom of movement again for 24 hours, after being confined for 3 to 4 days). Grimberg-Henrici *et al.* (2018) found higher levels of cortisol in group housed sows compared with individually crated sows, which might not be expected as these sows do not experience the effects of confinement and isolation. They proposed increased physical activity as the cause. This helps to explain the results of the current study; as evidenced in the behaviour recording, sows housed in the free lactation system utilised the space available to them to move around, and thus the opportunity to be more active could have increased the salivary cortisol concentrations of Free sows.

2.5.2 Behaviour

It could be expected that sows which are less stressed around the time of farrowing may have shorter farrowing durations. However contrary to the hypothesis, no effect of treatment with regard to farrowing duration was found. This is an important result as it shows that sows housed in free lactation pens are not affected negatively with regard to farrowing duration. Research suggests that confined sows exhibit an increased level of cortisol prior to farrowing (Lawrence *et al.*, 1994) resulting in an extended farrowing duration. Recent work by Nowland *et al*. (2019) which also used temporary confinement has resulted in similar findings to the current study with no effect of treatment on farrowing duration being observed (OPEN, crates were open until the sow stood following parturition CLOSED, crated were closed throughout parturition). Moreover, the sows in the free lactation pens had higher cortisol levels in the days after the move to the farrowing housing, even though they were not confined. Regardless of the reason for cortisol levels being higher (e.g. whether due to a relatively positive or negative affective state, compared to the standard crate treatment), the fact that the cortisol level was higher does suggest that there is some difference in welfare between treatments.

Moreover, because farrowing is already a stressful event, it is possible that once the sow has begun to farrow the environment has less influence over the stress response. Indeed (Yun *et al.*, 2015) found that housing type (farrowing crate, pen with sawdust, pen with abundant nesting material) did not affect oxytocin concentrations in sows during farrowing, and interestingly, found farrowing duration to be shorter in sows with confinement than those not confined.

Although the proportion of time sows spent standing or sitting was not affected by accommodation type, sows housed in free lactation pens tended to lie on their bellies more, with sows in conventional crates tending to spend a greater proportion of time lying laterally. Interestingly, sows in conventional crates spent significantly more time lying on the left side than those housed in free lactation pens. There is no explanation for this difference in the literature, it is possible that these sows were orienting toward the window in the room.

Regardless of whether sitting or lying, sows made use of all possible orientations in the free lactation pens, even though during most of the observations they were recorded as facing either the front or the back of the pen most frequently. This was most likely due to having most space along this line, as even though they could turn around completely, the width of the crate may not have been sufficient for them to lie comfortably across even when open. Thus, when given the opportunity, sows will remain more active during lactation than is possible in conventional farrowing crates. Indeed, the number of transitions per hour increased as lactation progressed. Reduced space allowance triggers stress responses in farmed animals (Proudfoot and Habing, 2015) and increased space allowance results in a reduction in damaging behaviour in pigs (Beattie *et al.,* 1996). The option to express a wider range of behaviours is generally accepted to improve welfare (Broom, 2011), and so being given the option to express more of their natural locomotory behaviour at this time may improve sow welfare.

The percentage of piglets in contact with the sow was not affected by treatment. It should be noted that sows in the free lactation treatment had the opportunity to move away from or push away piglets, but they spent the same amount of time in contact with their offspring as those housed in farrowing crates. This could be indicative of a higher level of maternal care in the free lactation sows.

2.6 Conclusion

It was hypothesised that the use of free lactation pens would improve sow welfare through improved physical health, greater allowance for expression of behaviour and lower levels of stress associated with confinement. The use of free lactation pens was seen to improve sow general physical health through decreased (better) locomotory score at weaning when compared with sows housed in conventional farrowing crates, despite higher levels of hoof damage. This is an important finding with implications for longevity and production, and for sow physical comfort. Furthermore, a greater range of expression of locomotory behaviour was observed in the free lactation sows, they made use of the extra space available to them and occupied all orientations in the pen. This shows that sows, when allowed to do so, will remain much more active around farrowing and lactation than they are currently capable of in the extremely restrictive farrowing crates. Lower levels of left eye tear staining seen in free lactation sows at weaning suggest reduced levels of stress. However, salivary cortisol results were surprising, with Free sows having higher cortisol concentrations overall.

The use of free lactation crates can be seen from this study to improve sow welfare in some regards, increased normal activity and improved locomotory health, however stress levels as measured by tear stain scores and salivary cortisol concentrations must be interpreted carefully. It is possible that the sows in free lactation accommodation were not in fact experiencing more stress, as higher cortisol levels may be interpreted, but were simply more active than their counterparts housed in farrowing crates. Salivary cortisol has been seen to indicate activity, and stimulation, not only stress. The sows in the free lactation pens had greater access to interact with their piglets and this may have resulted in them being mentally stimulated to a greater extent than the extremely confined sows in farrowing crates that could not turn around to interact with their piglets.

Chapter 3

Effects of Free Lactation Pens on Piglet Behaviour and Welfare

3.1 Abstract

A major concern in pig production is piglet mortality, especially due to crushing. While current farrowing systems use farrowing crates to reduce mortality, they present major animal welfare problems for the sow. This study investigated the effects of free lactation farrowing accommodation on the welfare (as measured by mortality, weight, behaviour) of piglets born and reared in such accommodation (to the sows described in chapter 2), when compared with conventional farrowing crates. Piglets were born to sows in one of two farrowing accommodation treatments and followed from birth to slaughter. Treatments were conventional farrowing crates (Control, n = 24 litters) and free lactation pens (Free, n = 22 litters) (675 total piglets). Piglets were tagged within 24 hours of birth, weighed, and their sex was recorded, cross-fostering was carried out within 48 hours and it was ensured that the number of piglets in a litter did not exceed the number of functional teats of the sow. Teeth were clipped and all but two litters had their tails docked (one from each treatment, excluded from analysis except mortality). Individual weights were recorded from birth to slaughter: weekly on day 7, day 14 and day 21 after birth, and at weaning (26.5 ± 1 days old), at move from weaner to finisher stage and once pigs met market weight (105kg). Hoof score was also recorded at weaning. Behaviour was recorded during lactation on day 8, day 15 and day 22 after birth, and during the weaner stage weekly for 3 weeks. Pre-weaning mortality was equal in both treatments (Free = 15.95 ± 2.31 piglets, Control = 14.42 ± 2.15 piglets, $P = 0.61$). Final weight was influenced by treatment ($P < 0.05$) with pigs from free lactation pens significantly heavier 114.73kg compared to 110.82kg for Control pigs. Free pigs took fewer days to reach the target weight of

105kg than Control pigs (147.6 *vs* 149.23 days), these improvements in final weight and less days to reach target weight are likely to offer significant profits for the producer, as well as indicating an improvement in welfare. Throughout lactation fewer instances of damaging behaviour (ear and tail biting) tended to be observed in Free pigs (P= 0.07). Pigs from the free lactation pens appear to be experiencing improved welfare when compared with Control pigs, this is evidenced by improved growth rates and a decrease in damaging behaviours.

3.2 Introduction

Optimising piglet survival is often the main reason cited to justify the use of conventional farrowing crates on commercial pig farms. The crate was designed to reduce piglet mortality by restricting the movements of the sow and allowing the piglets a safe space to where they can retreat as reviewed in Wischner *et al.* (2010). However, there are conflicting results in the literature with regard to piglet survival rates, when comparing farrowing crates with alternative farrowing housing that involve the sow being allowed freedom of movement. Weber *et al*. (2007) and Kilbride *et al.* (2012) reported no difference in mortality between crates and pens, whereas Blackshaw *et al*. (1994), and Marchant *et al*. (2000) reported greater mortality when sows are loose housed in pens.

Piglet mortality is influenced by a range of factors (e.g. litter size at birth, and the age or parity of the sow; Quiniou *et al.,* 2002, Weber *et al.,* 2007). Nevertheless, Weber *et al*. (2007) compared piglet mortality in loose pens and farrowing crates and found no difference in total piglet mortality; 1.40 piglets/litter in loose systems and 1.42 piglets/litter in farrowing crates. However, they also considered the cause of mortality, and reported more crushing in loose housing (0.62 piglets/litter) than farrowing crates (0.52 piglets/litter). Thus, overall mortality was equal due to significantly higher mortality from causes other than crushing in crates (0.89 piglets/litter) when compared with loose housing (0.78 piglets/litter). This demonstrates the complexity of the issue of pre-weaning mortality, and how factors which improve some aspects of animal welfare, may have a negative impact on others. Mortality due to crushing usually occurs within the first 4 days after birth, Marchant *et al.*, (2000) reported over half of liveborn mortality to occur at this time.

Piglets reared in alternative farrowing systems have been reported to weigh more than those reared in crates. Pedersen *et al*. (2011) found that piglets from free farrowing crates were heavier at weaning than those reared in conventional farrowing crates. Alternative systems often have a greater space allowance than conventional pens, and the sow also has freedom to self-select a lying location when she has freedom of movement. Thus, in pens where the sow has greater freedom of movement, piglets may have improved access to the udder. Indeed, milk let down lasts longer and fewer piglets miss milk let down in free pens, compared to traditional closed crate pens (Pedersen *et al.*, 2011).

Post weaning weight, and in particular weight at finish, are extremely important key performance indicators in pig production. As free farrowing pens have been shown to improve pre-weaning growth rates, they are also associated with heavier weaning weights. Weaning weight is an important predictor of post weaning performance, with heavier weaning weights associated with improved growth rates, and reduced days to slaughter (Rooney *et al.*, 2019, Wolter and Ellis, 2001). Thus if the improvement in growth pre-weaning is maintained post-weaning, the use of free lactation crates may offer production advantages to the producer, as well as benefits to sow and piglet welfare; however, to date the long term implications of 'free' lactation housing systems are under-researched.

Besides performance, housing systems which allow the sow and piglets greater freedom of movement and space can also affect other measures of welfare.

Increased space allowance and social contact, which are associated with loose housing, are generally recognised as important to improving animal welfare (Fraser, 2006). One aspect of piglet behaviour which could be affected by increased space and social contact is the performance of play behaviour. This has been shown to be very important in pigs, as they are highly motivated to perform such behaviour and it can have effects on social and cognitive development (Donaldson *et al.*, 2002). Thus, environments which promote rather than limit play behaviour may therefore result in increased welfare (Martin *et al.*, 2015).

The effects of an improved physical and social environment may also last beyond the time that pigs are managed there. For instance, piglets reared by loose-housed sows showed lower levels of damaging behaviour as well as more play behaviour post weaning than piglets reared by confined sows (Webster and Dawkins, 2000), which suggests that the lactation environment has a significant effect on the behaviour of pigs later in life. It is possible that providing the opportunity for increased interactions with the sow may improve the development of social behaviours which could make piglets better able to adapt to the stress of weaning (Oostindjer *et al.*, 2014).

Hoof health is another indicator of welfare and is important for physical comfort. Mouttotou and Green (1999) found the prevalence of sole bruising to be 50% in a study of 264 pre-weaning piglets on 13 farms in England. In most cases, claw injuries are superficial with no evidence of an effect on performance. However, if damage is severe it becomes a welfare issue and can also lead to the development of infection and lameness. It is therefore important that alternative farrowing systems do not negatively impact piglet hoof health. With the sow loose in the pen there may be a greater risk of injury to the piglets, and so hoof health was recorded in order to determine whether or not Free piglets sustained more hoof injuries when compared with Control piglets.

Many studies of chronic stress across a range of species report changes in cortisol concentration or circadian release of cortisol (Kobelt *et al.*, 2003, Tamashiro et al., 2005, Castillo *et al.*, 2009) and thus cortisol levels are commonly used as a marker of stress (Hellhammer *et al.,* 2009) in pigs (Blackshaw and Blackshaw, 1989), and other animals (Bayazit, 2009). A problem in assessing animal welfare is that the collection of such samples may be in itself stressful for the animal, therefore non-invasive methods are recommended both for animal welfare purposes, and to improve the quality of the data (Beerda *et al.*, 1996). Faecal samples offer the advantage that they can be easily collected without causing stress to the animal (Möstl and Palme, 2002). They may also provide a more long-term insight into an animal's cortisol levels than a 'snapshot' measure, such as blood or salivary cortisol levels, as the amounts detected are likely to be representative of a longer period of time. Faecal cortisol has not yet been measured in studies of piglet welfare and may be a useful tool in monitoring welfare on commercial farms.

The main aim of this study was to determine whether piglet welfare and performance is affected by the use of free lactation pens. Specifically, the study aimed to identify whether piglet behaviour, growth, hoof health, and cortisol levels differed when sows were managed in free lactation pens, compared with conventional farrowing crates. It was expected that piglet survival would be unaffected, whereas piglet growth and other aspects of welfare improved through the use of free lactation crates due to improved contact with the sow and increased space allowance.

3.3 Methods

A range of physical and behavioural measures were taken over the lifetime of the 675 piglets in the study to assess welfare and production. Piglet mortality was monitored throughout the study, piglets were weighed at various points from birth to slaughter, cortisol levels were determined from faecal samples collected, hoof scores were recorded at weaning, behaviour was observed during lactation and behavioural experiments carried out post weaning.

3.3.1 Treatments and experimental design

This study involved recording measurements on piglets reared by the sows, described in Chapter 2. In total 755 piglets were born, 308 to sows in conventional farrowing crates (Control), and 361 to sows in free lactation crates (Free). Details of the pen design (Figure 1) and general animal management and husbandry are as described in Chapter 2.3. In brief, Free pens contained crates which could be kept closed, as per a standard farrowing crate, or opened to allow the sow enough freedom of movement that she could turn around in the crate. In the Control treatment, standard farrowing crates were installed which remained closed with the sow confined from entry to weaning.

3.3.2 Animals and management

All piglets (Large White x Landrace) were tagged, weighed and their sex determined (there was no significant difference between treatments) within 24 hours of birth. Cross fostering was carried out where necessary, to ensure litter number did not exceed functional teat number, within 48 hours of birth, and thus out of those born, a final number of 675 remained in the experiment. The average number of suckling piglets in each litter in the Free treatment was 14.38 ± 1.95, and in the Control treatment was 14.79 ± 1.62. Piglets were never cross fostered more than once. Under veterinary advice piglets had their teeth clipped and all but two pens of piglets (one from each treatment, excluded from analysis other than mortality) had their tails docked during the first 48 hours. All piglets received an iron injection (Baycox®, Bayer Animal Health GmbH) on D5 *post-partum* and males remained fully intact. Creep feed was introduced at approximately 14 days old and distributed equally in both treatments. .. Enrichment in the form of hessian sacks and small natural fibre plant pots were introduced at approximately 12 days of age to both treatments. Records of any mortalities and their cause were kept daily.

At weaning (26.5 ± 1days of age) piglets were moved as entire litters without re-mixing to weaner pens which measured 2.4 m X 2.6 m; 6.24 m^2 , and had fully slatted plastic floors. The maximum number of pigs in a pen was 12 (i.e. 0.52 m^2/pig); in litters where more than 12 pigs were weaned, piglets which were lame or underweight were removed from the experiment at this point. Enrichment in the form of a rubber floor toy (Easyfix Luna 117®, Easyfix, Ballinasloe, Ireland) and a wooden spruce post was provided in every pen.

Pigs were moved to finisher pens (4 m × 2.4 m; 9.6 m^2) approximately 7 weeks post weaning and again remained in the same groups. Enrichment in the form of one hanging rubber chew device (Easyfix Astro 200®, Easyfix, Ballinasloe, Ireland) and a spruce wooden post were provided in each pen. Pigs spent 9 to 12 weeks in the finisher house before being sent to slaughter.

The temperature was maintained at 28°C immediately post-weaning in the weaner house by automatic heating and mechanical ventilation. Thereafter it was lowered by 2°C every 2 weeks. In the finisher house mechanical ventilation maintained a temperature of 20°C. Rooms were equipped with windows which enable the pigs to be in contact with natural light. Artificial lighting (150 lux in weaner house and 130 lux in the finisher house) was provided for 10 - 12 hours/day to ensure sufficient lighting to retain a normal circadian rhythm.

In both the weaner and finisher stage pigs were fed *ad libitum* via a single spaced wet-dry feeder with dry pelleted feed, with a nipple drinker providing water. Feed supply was managed via a computerised feed system (DryExact Pro, Big Dutchman, Vechta, Germany).

3.3.3 Experimental measures

Mortality

All cases and causes of mortality were monitored throughout the trial. In the farrowing rooms, dead piglets were examined for crushing injuries (traumatic injuries, e.g., bruises or visible impressions of the slatted floor on the piglet's body), and removal from the trial for other reasons such as hunger or injury were recorded. In the weaner and finisher stage cause of death and/or reasons for removal from the trial was determined by experienced farm staff.

3.3.3.1 Pre-weaning measures

Weight

Piglets were individually weighed within 24hrs of birth and on day 7, day 14, and day 21, and at weaning (26.5± 1 days of age). These data were used to determine the number of suckling piglets and the litter weight at each weighing, and piglet pre-weaning average daily gain (ADG).

Behaviour

Piglet behaviour was recorded for each pen 4 times per day on day 8, day 15, and day 22 of age by direct focal sampling for three minutes, twice in the morning (between 9.00 – 12.00) and twice in the afternoon (between 12.00 – 3.00). Behaviour was recorded by three observers: the observer stood outside the back wall of the pen and recorded all occurrences of locomotory, social, object directed and damaging behaviours, according to the ethogram described in Table 6.

Table 6: Ethogram used to record of piglet behaviours during lactation, adapted from Martin *et al.* (2015).

Category	**Behaviour**	**Description**
Locomotion	Scamper/Run	Two or more forward directed hops, running in a forward motion
	Pivot	Twirling around of the body, at least 90^{o}
	Hop	Either two front feet or all four feet off the floor
Social	Nudge	Snout used to touch another piglet's body
	Chase	Running after another piglet who is also running
	Social Interaction/Play	Sniffing, nuzzling by a piglet of another piglet's head, face, nose
	Sow Climb	Minimum of two feet off the floor and on the sow, not directed towards udder, climbing over udder or on sow's head, neck, shoulders
	Sow Nudge	Snout used to gently touch sow's body
	Sow Interaction	Sniffing, nuzzling sow's head, nose
Object	Pen	Rooting, biting, sniffing or any other oral behaviour directed to pen fixtures or the crate
	Enrichment	Rooting, biting, sniffing, or any other oral behaviour directed to enrichment materials
Damaging	Ear biting	Ear biting
	Tail biting	Tail biting
Fighting		Aggressive pushing, biting

Faecal cortisol

Piglet faecal samples were collected weekly, at approximately D12 (Mean ± SE) (4.58 ± 0.90 days of age), D19 (11.58 ± 0.90 days of age), D26 (18.58 ± 0.90 days of age) and D33 (24.58 ± 0.90 days of age) of the trial. A fresh faecal sample (approximately 5g), uncontaminated with urine, was collected from various locations in an effort to ensure the sample was representative of the whole pen, out of reach from the sow to minimise contamination, and placed in a sealed plastic vial, then stored at -20°C until analysis. Prior to analysis, 5ml of 80% methanol was added to 0.5g faeces and centrifuged at 2500 rpm for 15 minutes as described in Palme *et al.*, (2013). Following this, the same EIA kit which was used for salivary cortisol analysis for the sows (see Chapter 2.3.3.1) was used to determine cortisol concentration.

Hoof scores

The condition of piglets' hooves was assessed at weaning. All four hooves were examined and individually scored using a scoring system adapted from Lewis *et al.*, (2002) (Table 7).

Table 7: Piglet hoof scoring adapted from Lewis *et al.*, (2002).

Score	Description	
0	No damage	
1	Mild bruising	
2	Severe bruising and/or small cut(s)	
3	Large cut(s) and/or swelling	 
4	Hoof deformed/partially or fully amputated	 

3.3.3.2 Post-weaning measures

Only pens with 11 or 12 pigs at weaning (13 Free pens and 12 Control pens) were included in post-weaning analysis, in order to control for the effect of space allowance on performance and behaviour measurements.

Live weight and performance

Pigs were individually weighed unfasted at move from the weaner house to the finisher house and at weekly intervals once they approached slaughter weight (starting on week 9 of the finisher stage). At each recording day those that weighed over 105 kg were sent for slaughter. On week 12 after entry to the finisher stage all remaining pigs were sent for slaughter, regardless of reaching the target weight. Feed quantity delivered to each pen in the weaner and finisher stage was downloaded daily from the feed system. These data were used to calculate the average daily feed intake (ADFI) at pen level until the recording day that the first pigs went to slaughter. Combined with pen weights at weaning, the move to the finisher house and at the first slaughter date, average daily gain (ADG) and feed conversion efficiency (FCE; ADFI / ADG) for both weaner and finisher stages were calculated.

Behaviour

Pigs were subjected to behaviour tests on days 8, 15 and 22 after move to the weaner pens. A one-week delay in commencing these tests was to ensure that pigs were habituated to their new environment. Four standard tests were carried out in the same order on each testing day in order to standardise the testing procedure. The pen order for testing was randomised. An inter observer reliability test was carried out and all observers were trained by a single trainer.

1. Startle test

The startle test measured reaction to a sudden event, and the capacity of the pigs to recover. The observer opened an umbrella over the pen and immediately started a timer using a stopwatch. The startle reaction of the pigs was scored as follows; 1 = at least 60% of pigs in the pen were startled, or 0 = less than 60% startled. 'Startled' was defined as the pigs stopping whatever activity they had been engaged in and being immobile for at least one second. In startled groups the latency for the group to return to normal behaviour after the startle was recorded.

2. Novel object test

Immediately after the startle test, the pigs' reaction to a novel object was observed by placing a 20L blue water bottle in the middle of the pen and recording the latency for the first pig to make contact with the object. If no pigs made contact with the object within 3 minutes the test was terminated.

3. Human animal relationship test (HART)

After the novel object test two human animal relationship tests were conducted. The first part measured the group reaction toward the presence of a human and the second part measured the response of each individual pig to human contact. For the first test (HART1) the experimenter entered the pen and scored the panic response of the group as follows; 0 = less than 60% show panic response, fleeing or facing away from the human, and 1 = over 60% show panic response (as described in Welfare Quality 2009). The second test (HART2) was carried out immediately after HART1, and adapted from Welfare Quality (2009), as per Schmitt *et al.* (2019). Any pigs which showed fear to human approach and contact were scored 1 and pigs accepting human contact were scored 0. The experimenter was familiar to the pigs having handled them regularly from birth.

4. Open door test

The final test assessed pigs' willingness to exit the pen and explore a new area, the corridor, as per Schmitt *et al.* (2019). Immediately following the HART tests, the door of the pen was opened approximately 30cm by the experimenter, who remained still and silent. Pigs were free to exit the pen for up to 3 minutes, after which the test was terminated. The latency to first exit and number of pigs outside the pen at 1 minute 2 minutes and 3 minutes were recorded.

3.3.4 Statistical analysis

All data were analysed using SAS v 9.4. Results were deemed statistically significant when α level was below 0.05, and a significant tendency was considered when α level was between 0.05 and 0.1. Either the Tukey-Kramer or Bonferroni adjustments were used for multiple comparisons where least squares means (LS means) were determined and P-values were adjusted. Degrees of freedom were estimated using Kenwood-Rogers adjustment. For data that were analysed using general linear models, data are presented as least square means and standard errors. PROC UNIVARIATE was used initially for evaluating data distribution. Two sows and their litters were excluded from all analysis due to removal from trial for a shoulder injury and savaging of piglets.

Pre weaning measurements

The percentage mortality and the percentage of piglets weaned (inverse relationship to each other) were analysed using general linear models (Proc Mixed). For this analysis, the parity of the sow was categorised as 0 (n = 10), parity 1 and 2 (n = 16), parity 3 and 4 (n = 9) or parity 5 and 6 (n = 13). The model included the fixed effects of treatment, parity category, the interaction, and replicate. The number of piglets in the pen after cross fostering was used as a covariate.

As well as this, the cause and timing of death were examined for pens that had at least one piglet die. Causes were defined as crushing, hunger (as evidenced by failure to thrive, and this included piglets which were removed from the trial) and euthanized. The day of death was log transformed so that residuals had a normal distribution. The effect of treatment on the causes of death and the day of death was analysed using the same linear mixed model. Treatment, cause of death, the interaction, parity, and replicate were included as fixed effects. Fishers exact test was also carried out for each of the causes of death, to determine whether there was a difference in rates of death due to each cause before or after day 4 across treatments.

For analysis of piglet weights the sow was used as the experimental unit, and two models were used. The first model investigated weights on each recording day. The model included the fixed effects of treatment (Control versus Free), whether the mother was primi- or multiparous (Gilt versus Sow), the day of weighing (D7, D14 and D21), all interactions between these factors, as well as the experimental replicate. Birth weight and the number of piglets in the litter were included as covariates. Day of weighing and piglet were included as repeated effects, with a direct product compound symmetry structure included to account for covariance between piglets and over time. The second model was used to analyse both weaning weight, and average daily gain to weaning. The same fixed and repeated effects were used as before, but with the exclusion of day. The number of days between birth and weaning was included as an additional covariate. A compound symmetry covariance structure was specified.

Pre-weaning behaviours were expressed as the percentage of piglets in the litter performing the behaviour at each observation time. The percentage of piglets resting, and at the udder were analysed, as well as the main behaviour categories in the ethogram (locomotion, social, exploratory behaviour and negative behaviours). As well as this, the sub-categories of piglet directed and sow directed social behaviour, interaction with the enrichment, tail and ear biting behaviours, and fights were considered. The data for each day were averaged over the four recording periods. For interaction with the enrichment, only data from the second and third recording days were used, as the enrichment materials had not yet been placed in the pens at the first recording day. Data were analysed using a general linear model (PROC MIXED). Fixed effects included treatment, recording day, the interaction, and replicate. Recording day was included as a repeated measure with an Autoregressive covariance structure. Damaging behaviour had 0.01 added to each value, to account for 0 values, and was then log transformed.

Piglet faecal cortisol levels were also analysed using a general linear mixed model (Proc Mixed). Fixed effects were the treatment, sample day, the interaction, whether the mother was a gilt or multiparous, and the replicate. Sampling day was considered a repeated measure.

Piglet hoof scores were analysed using a generalised linear model (Proc Genmod). Fixed effects were treatment and whether the mother was a gilt or multiparous, as well as replicate.

Post weaning measurements

For post-weaning weights, only pens containing 11 or 12 pigs were analysed to ensure no confounding of treatment by number of pigs in pen: 12 Control pens and 13 Free pens. The pen was considered the experimental unit. Two models were used; the ADG, ADFI, weight at the end of each stage (for finishers up to the day that the first pigs were sent to slaughter), and the FCE in the weaner and finisher stages were analysed using the first model. Fixed effects included treatment, stage and the interaction, as well as replicate, and the number of pigs in the pen. Stage was included as a repeated effect, with a compound symmetry covariance structure. The second model was used to compare the days to slaughter (from birth) and the weight at which pigs went to the factory. In this model, fixed effects were the treatment and replicate, and the number of pigs in the pen.

The pen reaction to the startle test (i.e. whether the pen showed a startle response or not) was analysed using a generalised linear model (Proc Glimmix). Only test results from the second and third tests were analysed, as on the first test all pens had a startle response. Fixed effects included the treatment and the replicate. The latency to return to normal was analysed using a general linear model (Proc Mixed). Fixed effects included the treatment, test day, the interaction and the replicate. Test day was included as a repeated effect.

Latency to make contact with the novel object was analysed using a similar model to that listed above. By the third test all pens had a latency of under 6 seconds, and 9 in total had a latency of 0, and as such these data were removed from statistical analysis.

The HART1 was analysed using a generalised linear mixed model, with each test day analysed separately as for the startle test. The HART2 test was analysed using a general linear model, again with the same fixed and repeated effects as for the latency to touch the novel object.

The latency for pigs to exit the pen was log transformed so that residuals approached normality. Data were analysed using a general linear model (PROC MIXED). Fixed effects included treatment, recording day, the interaction, and replicate. Recording day was included as a repeated effect.

3.4 Results

3.4.1 Mortality

There was no effect of treatment on the percentage mortality or percentage of piglets weaned (Table 8). However, there was an effect of parity category on both percentage mortality and percentage piglets weaned ($P < 0.001$ for both; Figure 15). Sows of parity 5 and 6 had significantly higher mortality than those of parity 0 (i.e. gilts; $P < 0.001$) and the cluster of sows of parity 1 and 2 ($P < 0.01$). Sows of parity 3 and 4 also tended to have a higher mortality level than gilts ($P = 0.06$).

In total, 125 piglets died prior to weaning. Out of these, the exact cause of death and day was known for 109 piglets. With regard to the day of death, there was no effect of treatment.

Table 8. Mortality data for piglets reared in free lactation crates (Free) and conventional farrowing crates (Control) prior to weaning.

	Free	**Control**	**P-value**
Initial litter size[1]	14.64 ± 1.47	14.79 ± 1.61	NA
% mortality	15.95 ± 2.31	14.42 ± 2.15	0.61
% weaned	84.05 ± 2.31	85.58 ± 2.15	0.61
Day of death[2]	6.14 ± 1.65	8.69 ± 1.31	0.43

[1] Unanalysed mean ± standard deviation provided

[2] Least squares means were calculated by running raw data through the model, and P-values by running log transformed data.

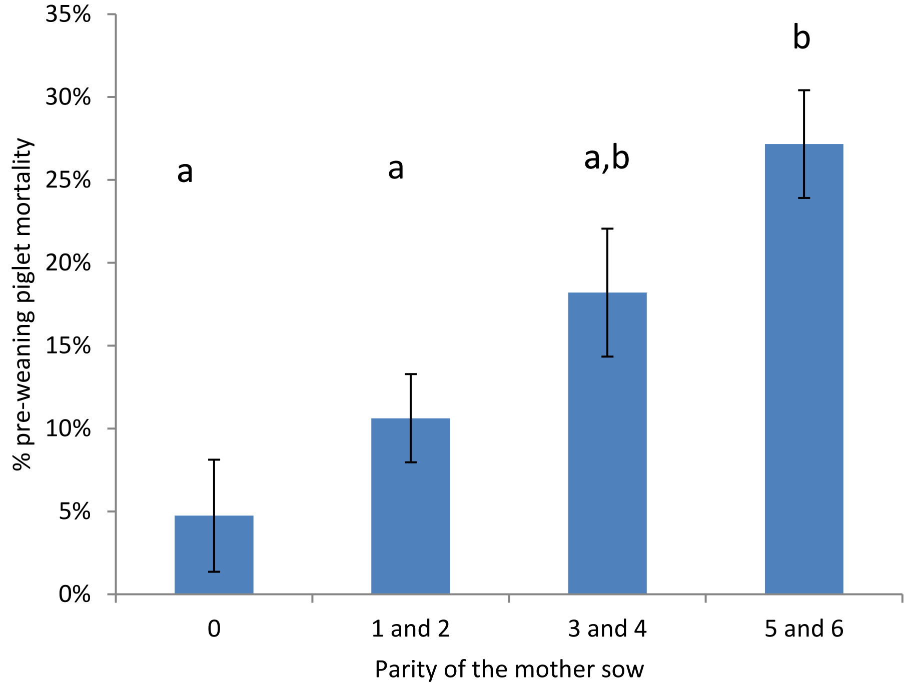

Figure 15. Mean ± SE percentage mortality prior to weaning in sows of various parities. a, b indicate a significant difference at P < 0.01.

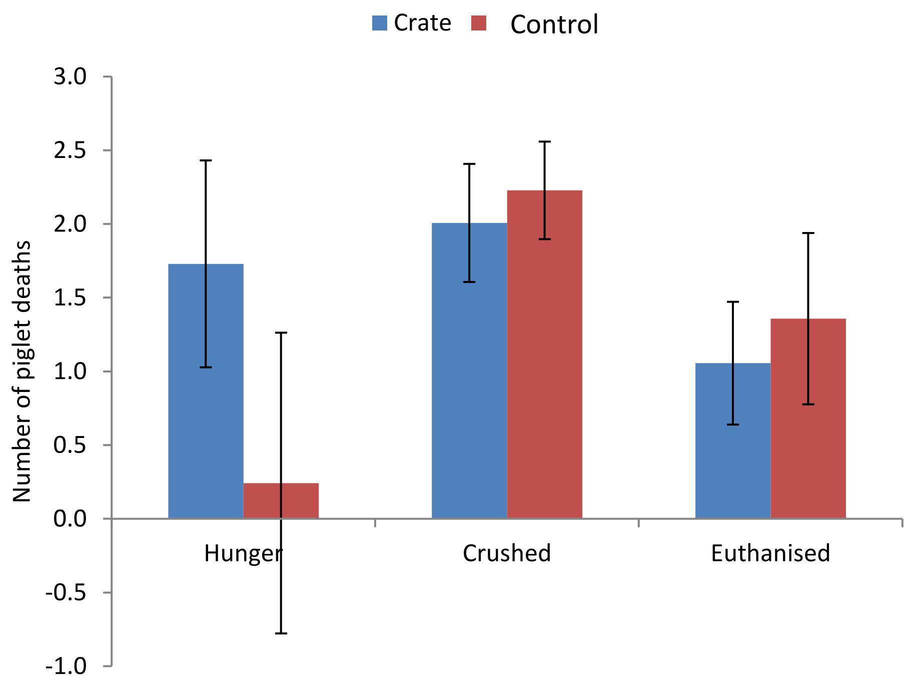

Figure 16. Mean ± SE causes of pre-weaning mortality in piglets from the free lactation pens (Free) and conventional farrowing crates (Control).

Details of the causes of death before and after opening of the crate (morning of day 4 after farrowing) are outlined in Table 9. More piglets were killed due to crushing in the Free treatment (n=26) after the crate was opened than in the Control (n=9). Although numerically more piglets in Control died due to hunger after day 4 (n=11), the difference was not significant.

Table 9. Causes of death in each treatment prior to and after the day the crate was opened (morning of day 4 post farrowing) in the Free and Control treatments. Numbers of piglets which died due to each cause before and after were compared across treatments using Fishers exact test.

	Control	**Free**	**P-value**
Crushing			
Before D4	21	17	0.017
After D4	9	26	
Hunger			
Before D4	0	1	0.214
After D4	11	2	
Euthanasia			
Before D4	8	6	0.649
After D4	6	2	

3.4.2 Performance pre-weaning

Pre-weaning, there tended to be an interaction between treatment and day (P = 0.08), with piglets from the Free treatment being heavier, although not significantly, on day 14 and day 21 after birth (Figure 17).

There was no effect of treatment on average daily gain during lactation (Free = 0.429 ± 0.007 kg/day, Control = 0.233 ±0.007 kg/day; P = 0.13) or on the total litter weight weaned (Free = 86.29 ± 0.84 Kg, Control = 86.47 ± 0.86 Kg; P = 0.86). Nevertheless, there was a trend for individual weaning weight to be higher in Free pigs, 7.83 ± 0.19 kg, than Control pigs, 7.40 ± .18kg (P = 0.12).

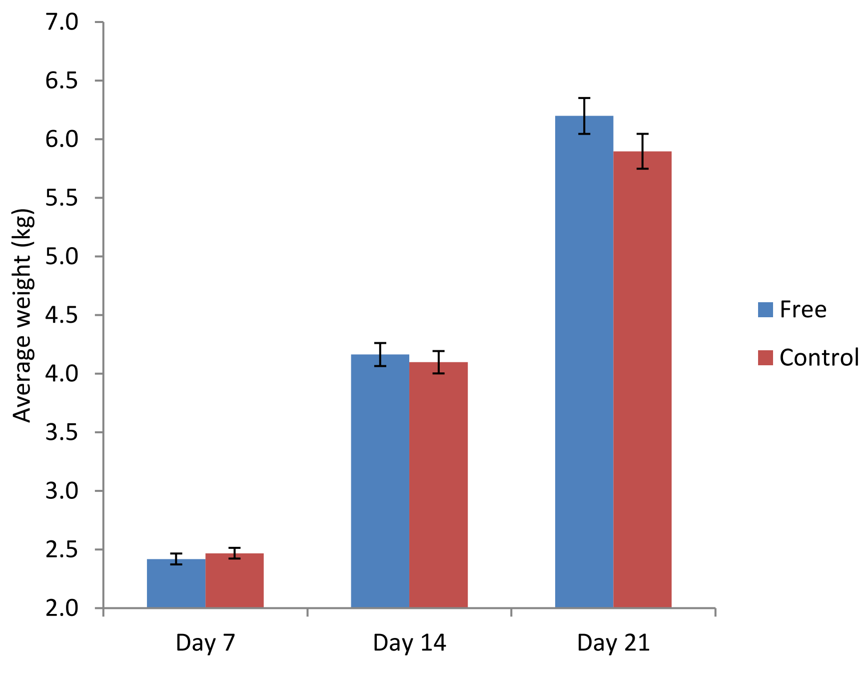

Figure 17. Mean ± SE piglet weights on days 7, 14 and 21 after birth, for piglets born and reared in free lactation pens and conventional farrowing crate pens.

3.4.3 Performance post-weaning

Post-weaning mortality was 3.66% in the Control treatment and 2.81% in the Free treatment, although this was not statistically analysed.

Pigs reared in the Free treatment had a higher ADG overall (0.829 ± 0.014 g/day) than those in in the Control (0.782 ± 0.013; $P < 0.05$). This difference was significant in the weaner stage ($P < 0.05$) although not in the finisher stage (Figure 18A). There was no effect of treatment on ADFI either overall or in either stage (Figure 18B). Overall, pigs from the Free treatment tended to have better FCE (1.87 ± 0.03 g/g) than those from the Control (1.94 ± 0.02 g/g; $P = 0.07$), and this was significant in the weaner stage (Figure 18C; $P < 0.05$), but not in the finisher stage.

With regard to the entire pen weight, again pigs from the Free treatment performed better. They tended to be heavier than those from Control at move from weaner to finisher stage ($P = 0.06$) and were significantly heavier by the end of the finisher stage, when the first pigs were sent to slaughter (Figure 19; $P = 0.01$). Days to slaughter was significantly influenced by treatment (Figure 20; $P < 0.05$), as was final slaughter weight (Figure 21; $P < 0.05$) with Free pigs taking fewer days to reach the target weight of 105kg, and weighing more at this time than Control pigs.

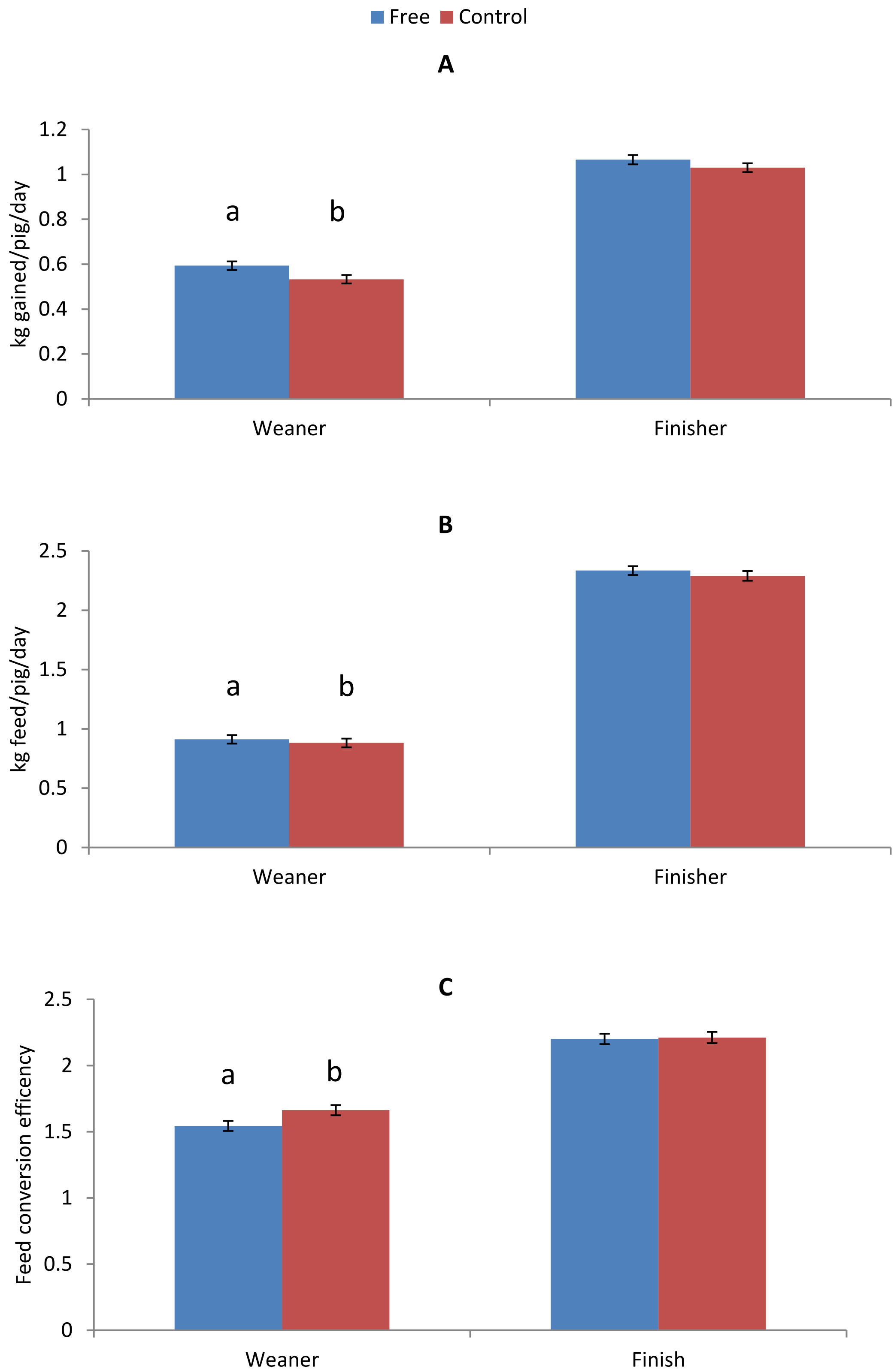

Figure 18. A. Average daily gain ± SE (ADG), **B**. Average daily feed intake (ADFI) and **C**. Feed conversion efficiency (FCE) for pigs from Free and Control treatments post-weaning. a, b indicate a significant difference at P < 0.01.

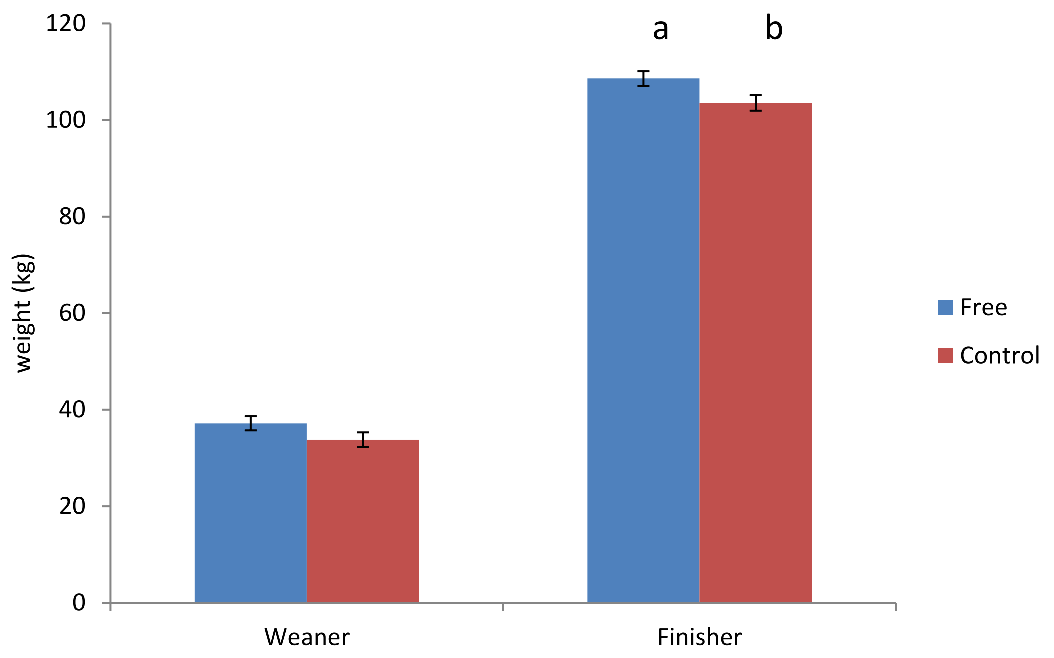

Figure 19. Mean ± SE Pen weights at end of weaner stage and end of finisher stage. a, b indicate a significant difference at P < 0.01

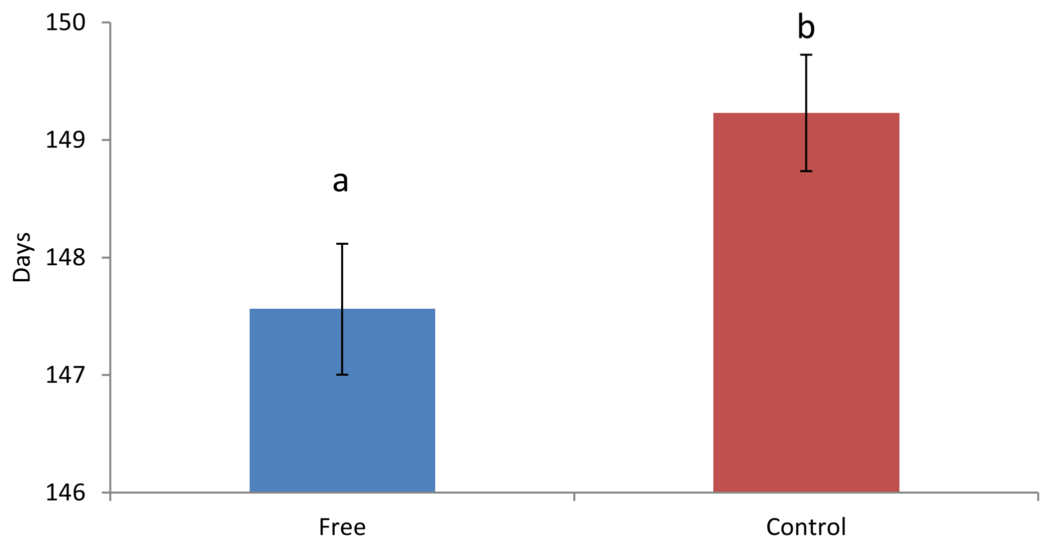

Figure 20. Mean ± SE days to slaughter for pigs born in free lactation pens and conventional farrowing crates. a, b indicate a significant difference at P < 0.01

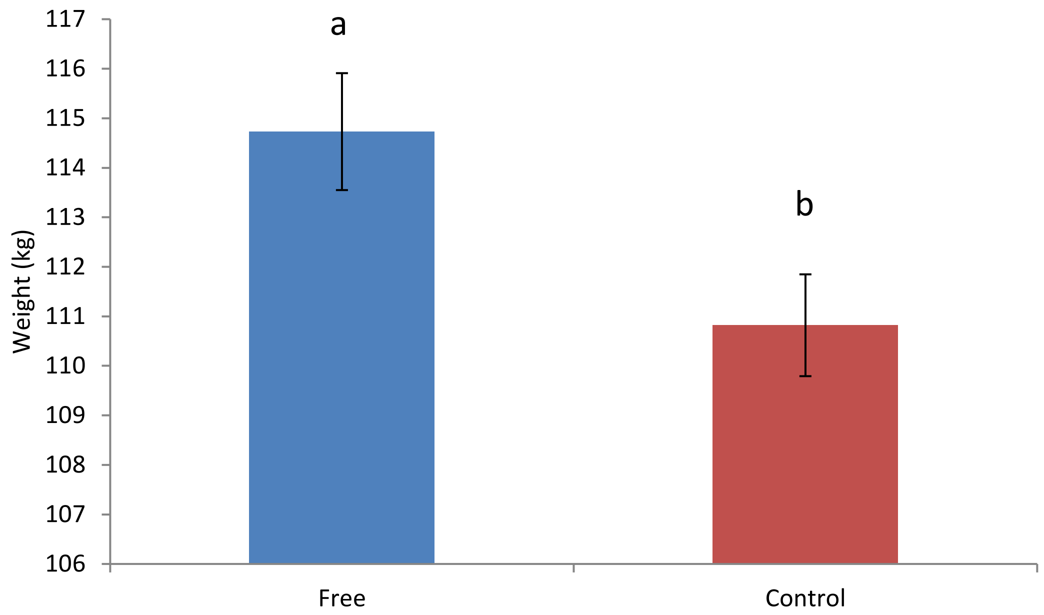

Figure 21. Mean ± SE final weight for pigs from Free and Control treatments, taken the day before pigs were sent to slaughter. a, b indicate a significant difference at P < 0.01

3.4.4 Behaviour pre-weaning

In the Free treatment piglets were observed more often at the udder ($P < 0.05$) than those in Control. Social behaviour was not affected by treatment (Figure 22). With regard to damaging behaviour, there was no effect of treatment on fighting, and although there was an interaction between treatment and observation day ($P < 0.05$), there was no difference on any individual day (Figure 23). However, as seen in Figure 24, there tended to be fewer instances of damaging behaviour (ear and tail biting combined) observed in Free pigs than in Control pigs ($P = 0.07$).

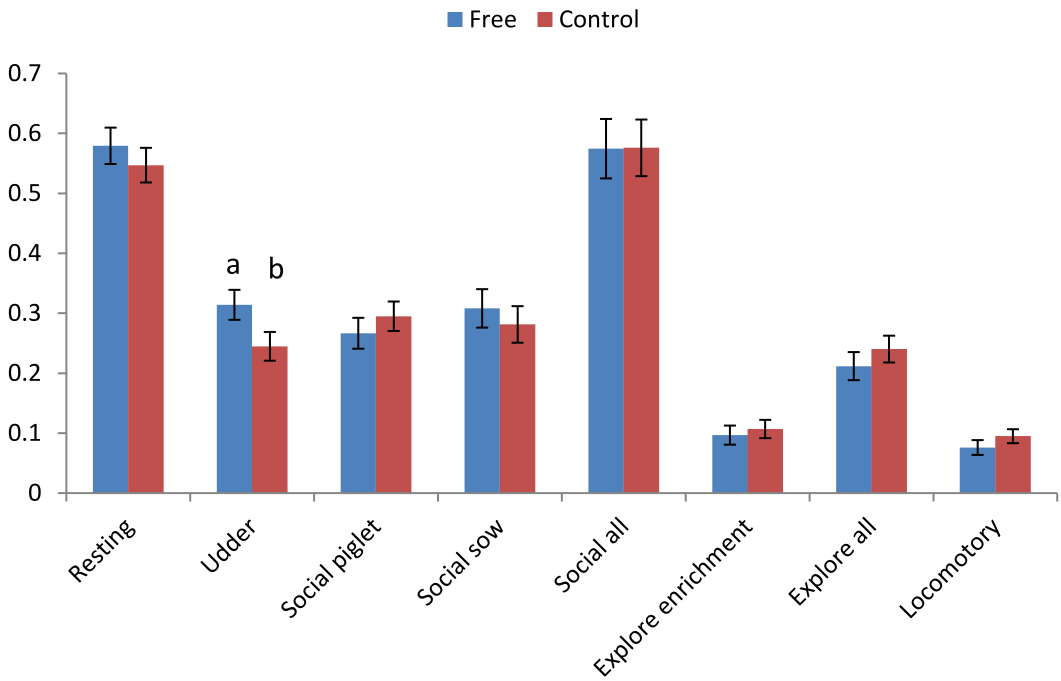

Figure 22. Piglet behaviours during lactation for piglets in free lactation pens and farrowing crate pens. Piglets in free lactation pens spent more time at the udder (P = 0.04), there was no effect of treatment observed on the other behaviours recorded. a, b indicate a significant difference at P < 0.01

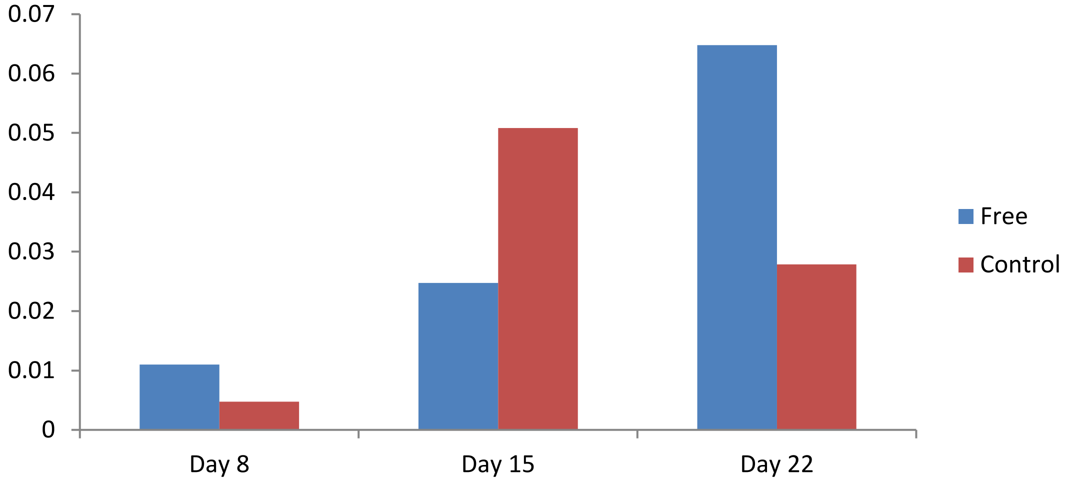

Figure 23. Fighting behaviour observed in free lactation pens and conventional crates on days 8, 15 and 22 after birth. Means are presented as back transformed logarithmic values, as data were analysed using a log transformation.

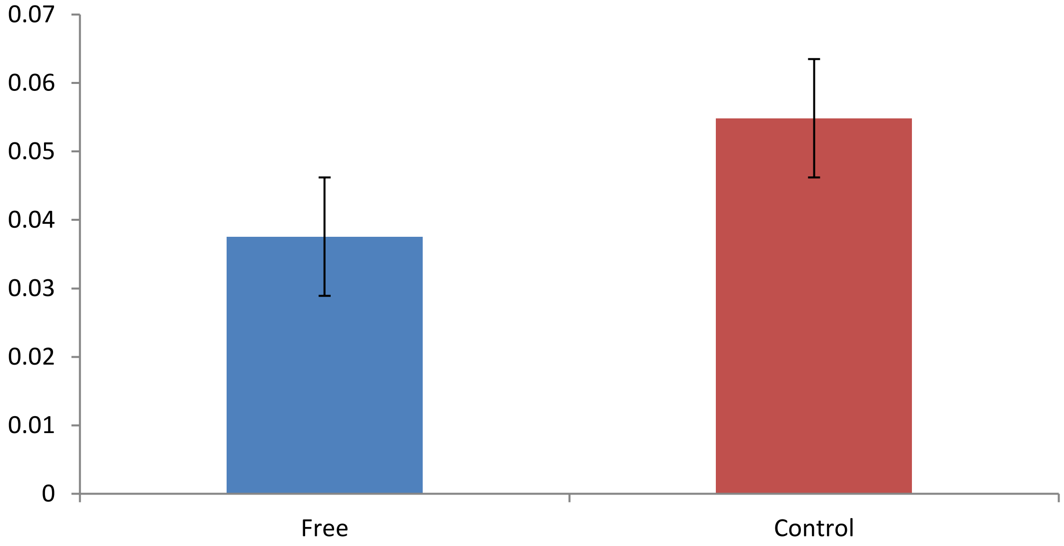

Figure 24. Damaging behaviour observed in free lactation pens and traditional crates. Piglets in free lactation pens performed fewer damaging behaviours, ear and tail biting, than those in crates ($P = 0.07$).

3.4.5 Faecal cortisol and hoof scores

Overall there was no effect of treatment on faecal cortisol concentrations (Free =0.553 ± 0.159 µg/dl, Control = 0.386 ± 0.148 µg/dl; P =0.14). Nevertheless, there was an interaction between sampling day and treatment (P < 0.01; Figure 27). On the first sampling day, which corresponded to 0.5 ± 1.09 days after the crate was opened in the Free treatment, piglets in this treatment tended to have higher faecal cortisol levels than those from Control (P = 0.07).

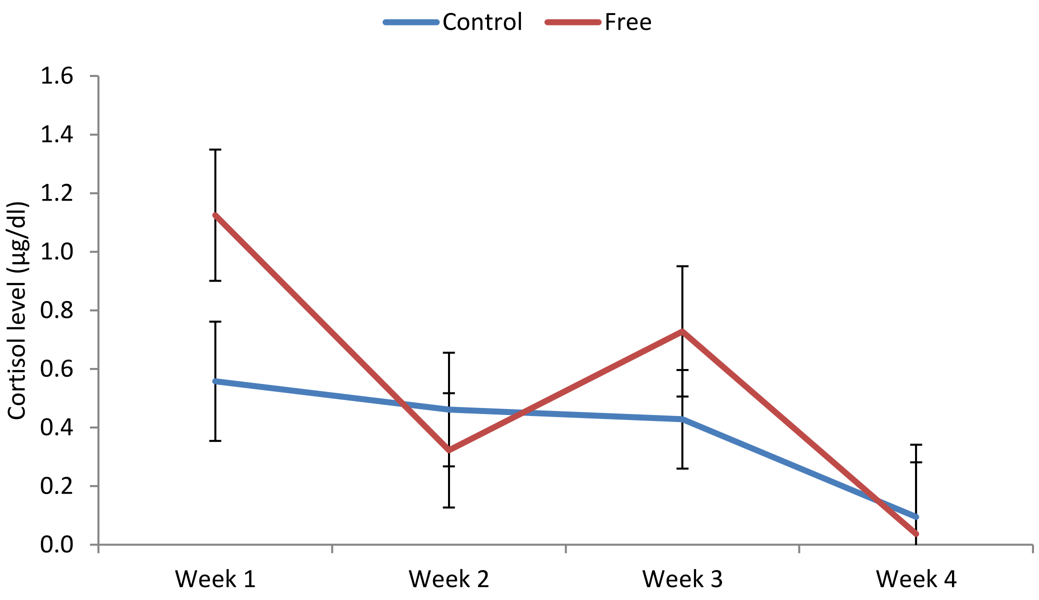

Figure 25. Mean ± SE faecal cortisol levels for piglets in Free and Control treatments once per week throughout lactation.

There was no effect of treatment on piglet hoof scores at weaning (P = 0.57), Median (interquartile range) for piglets from both treatments 4 (2 – 6).

3.4.6 Behaviour post-weaning

There was no effect of lactation housing on the number of pens which startled, or in the time taken to recover after startle between treatments (Figure 26).

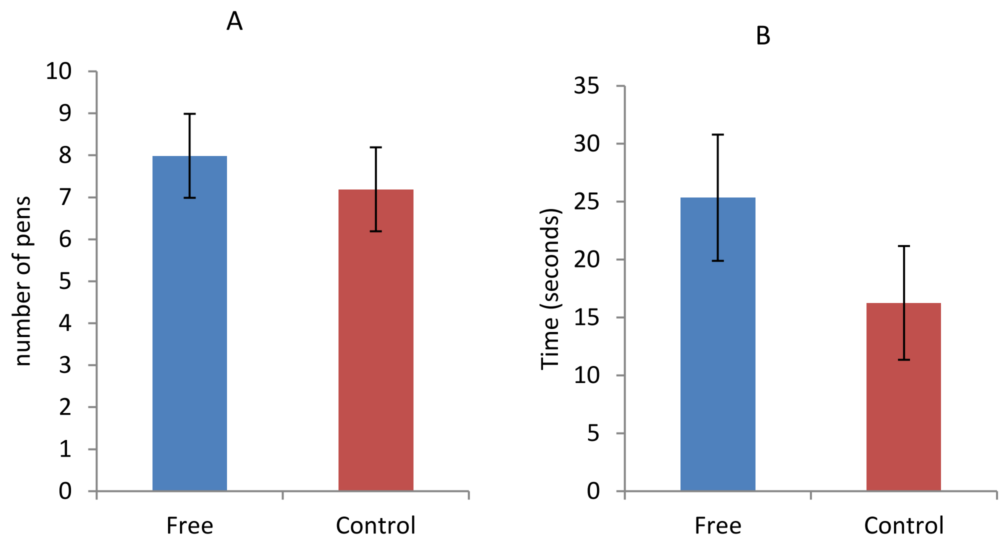

Figure 26. Startle test. **A**. Mean ± SE proportion of Free and Control pens which showed a startle response (over 60% of individuals in pen startled). **B**. Mean ± SE time taken for pigs from Free and Control to recover after the startle test

The time taken to approach the novel object reduced between the first and second test in both treatments ($P < 0.001$). Overall, Free pigs took longer to approach the novel object than Crate ($P < 0.05$). There was also an interaction between treatment and test day however ($P < 0.05$); on the first test day (i.e. one week post weaning) pigs from the Free treatment took longer to approach the object than those from Control ($P < 0.05$) , whereas there was no difference on the second test day (two weeks post weaning; Figure 27).

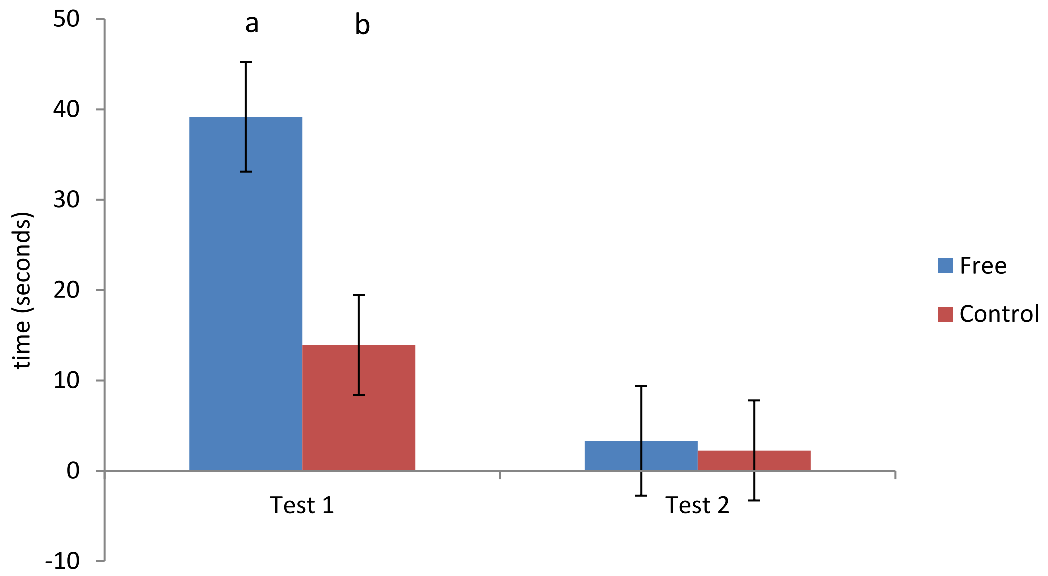

Figure 27. The mean ± SE latency of pigs reared in free lactation pens (Free) and traditional crates (Control) to approach a novel object one week (Test 1) and two weeks (Test 2) after weaning. a, b indicate a significant difference at $P < 0.01$

There was no effect of treatment with regard to HART1 (i.e. panic response to a human entering the pen). Neither was there a difference in the percentage of pigs which ultimately touched the human during the test (HART2).

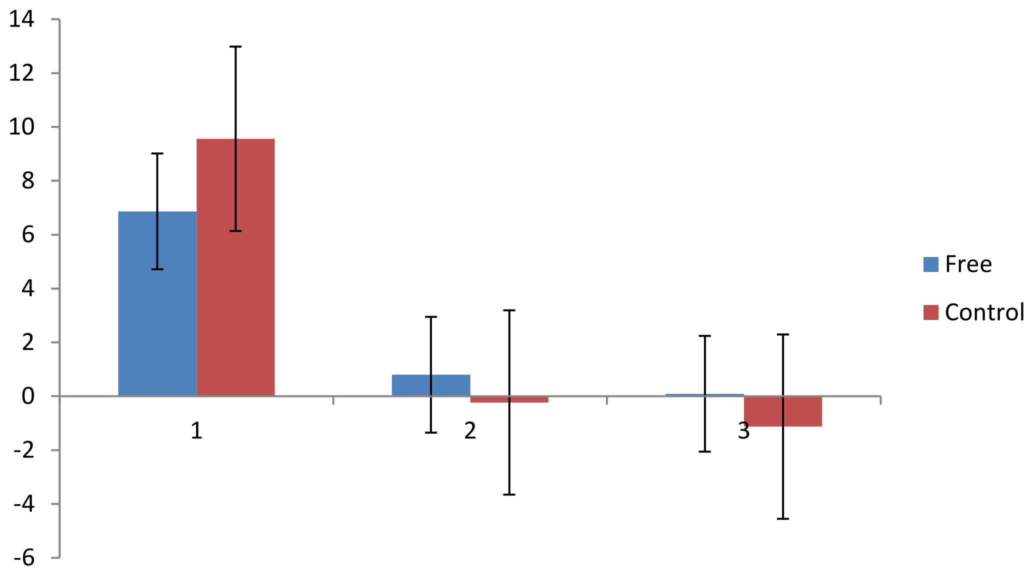

Figure 28. Human animal relationship test on week 1, 2 and 3 after entry to weaner stage. Mean ± SE willingness to accept human approach and contact (0) or fear of human approach and contact (1).

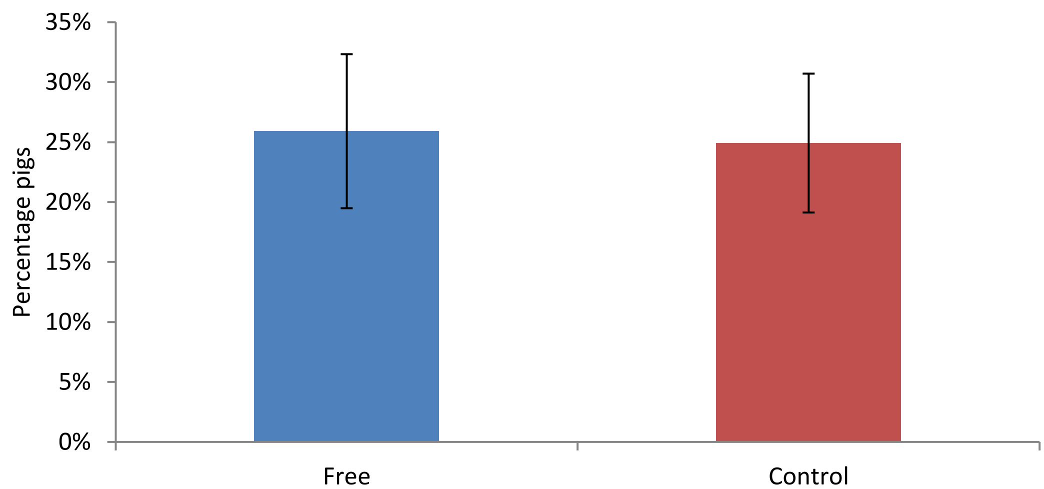

Figure 29. Human animal relationship test. Mean ± SE percentage of pigs from free lactation pens and conventional crates showing fear to human approach and contact.

With regard to the open door test, there was no effect of treatment on the time taken to leave the pen when the door was opened (figure 30 A; P= 0.82), nor was there any effect of treatment on percentage of pigs which left the pen within the 3 minutes of the door being opened (figure 30 B; P= 0.78). Across all tests 89% of Free and 88% of Control pigs exited the pen.

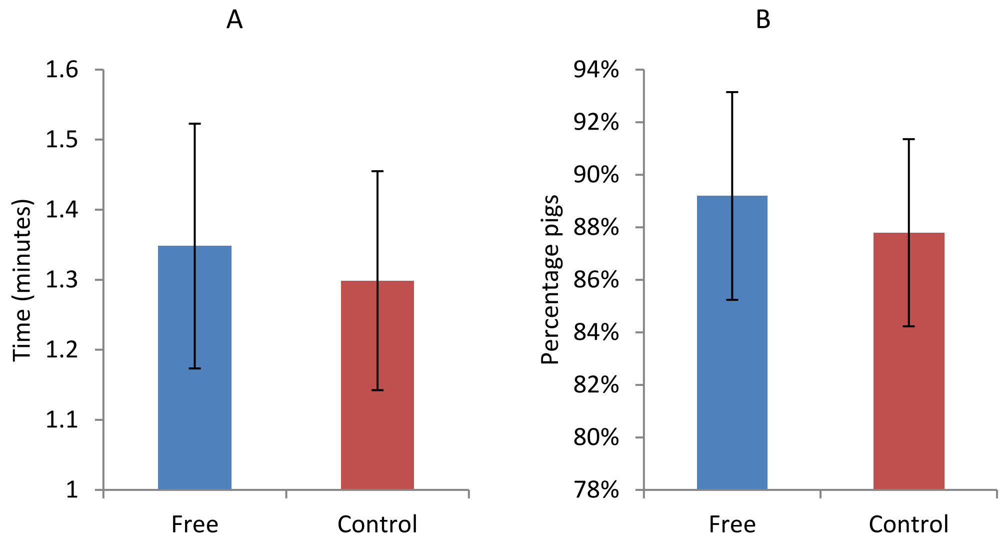

Figure 30. Open door test. **A**. Mean ± SE latency of pigs from Free and Control to exit the pen when the door was opened. **B**. Mean ± SE percentage of pigs from Free and Control which exited the pen within the 3 minutes that the door was opened.

3.5 Discussion

The slow move toward alternative farrowing systems in Ireland which can benefit sow welfare through increased freedom of movement has been influenced by concerns around pre-weaning piglet mortality due to crushing. This study however shows that free lactation pens which only temporarily confine the sow can deliver the same level of piglet survival as farrowing crates. Pigs reared in free lactation pens also performed better taking fewer days to reach target weight and finishing at a heavier weight than those reared in farrowing crates.

3.5.1 Mortality

Piglet mortality was similar in both treatments. One of the primary negatives associated with free farrowing systems is that there is generally a higher risk of crushing (and as a result overall mortality levels), and although it was found that this was the case once the crates were opened, it is encouraging that overall, using the management strategies employed this problem can be avoided. Indeed the strategy of opening crates on day 4 post-farrowing, and thus imposing a 'free lactation' management system rather than 'free farrowing' appeared to mitigate many of the risks of the system; it is well acknowledged that the first three days post farrowing is the period of highest risk for crushing of piglets (Marchant *et al.*, 2000).The time of day that the crate is opened can also influence the risk of crushing; King *et al.* (2018a) found mortality to be lowest in crates opened in the afternoon rather than in the morning. In the current study crates were opened in the morning due to farm management limitations, and as such it is possible mortality could have been reduced further if opening had been in the afternoon.

It is important not to overlook factors other than crushing which influence mortality; this is a complex issue where individual sows have differing maternal characteristics which can impact piglet survival. In line with these findings, Hales *et al.* (2014) also found that mortality increased with increasing parity, as well as with increasing litter size. King *et al.* (2018) found that the sows' previous experience in a farrowing system affects piglet mortality. Thus, the older sows in this experiment which were in the Free treatment may have had lower rates of mortality if they had previous experience of farrowing in such accommodation. Although not statistically significant, numerically fewer piglets from the Free treatment died from hunger or had to be euthanized. This likely compensated for the increase in crushing after the crates were opened, the result of which being similar overall mortality levels pre-weaning.

With regard to the future of pig farming, a risk for free farrowing or lactation systems is the ongoing increase in litter size. Although there is the potential for greater productivity, there could also be more mortality. Larger litter sizes result in increased weight differences in litters, poorer lifetime performance and more piglets born dead. Smaller piglets are at greater risk of crushing; therefore, reducing litter size to a more manageable level for sows could improve mortality rates, place less stress on the sow, and improve welfare for sow and piglet.

The finding that numerically fewer piglets from the Free treatment died from hunger than those from the Crate is in line with the results regarding pre-weaning performance. The interaction between treatment and the weighing days showed that piglets from the Free treatment became increasingly heavier than those from the Control as time progressed. This translated into a tendency for a heavier weaning weight, and greatly improved post weaning performance. There are a number of factors which could have contributed to this. Piglets could have had improved access to the udder due to the extra space around the sow, and indeed piglets were observed at the udder more often in the Free treatment than the Control. Although not measured in this study, milk let-down has been found to last 1.8s longer in free farrowing pens (Pedersen *et al.*, 2011). That study also found that piglets had fewer teat fights and fewer piglets missed milk let-down in free farrowing pens, both of which are advantageous for growth. As a result, other studies have also found piglets reared in free farrowing pens to be heavier at weaning than those in farrowing crates (Chidgey *et al.*, 2015). These results suggest that providing the sow with an increased level of freedom during lactation not only has benefits for her own welfare, but also for her piglets.

3.5.2 Performance

As stated above, pigs reared in the Free treatment had not only a tendency for improved growth pre-weaning, but had greatly improved performance post-weaning, particularly in the weaner stage. The greater average daily gain, combined with a lack of difference in feed intake, resulted in a better (lower) feed conversion efficiency. The weaner stage is a very stressful transition marked by changes in environment, feed and separation form the sow, and this often results in reduced feed intake. Therefore, any improvement in ADG at this stage may indicate that pigs are less stressed and is likely to be advantageous with regard to production.

Overall pen weights from the Free treatment tended to be greater than those from the Control at the move from the weaner stage to the finisher stage and were significantly heavier after 9 weeks in the finisher stage (when the first pigs went to slaughter). This difference in weight at finish is likely to offer a significant improvement in profitability for the producer and may also indicate higher welfare in the animals. Days to slaughter was also significantly reduced in pigs reared in the free lactation treatment, again benefiting production with pigs reaching a heavier finish weight over a shorter period of time without any increase in feed intake.

3.5.3 Behaviour pre-weaning

As well as being observed more often at the udder, piglets from the Free treatment performed a lower amount of damaging behaviour. Although this difference was not significant, a reduction in damaging behaviour could be an indication that piglets are less stressed; ear and tail biting in pigs are abnormal behaviours associated with stress (Schrøder-Petersen and Simonsen, 2001). Martin *et al.* (2015) found that piglets born in alternative farrowing pens displayed play behaviour sooner and played more during the pre-weaning stage than those born in crates. That study also found that free farrowing crate piglets displayed less damaging behaviour post-weaning. Ursinus *et al*. (2014) found that tail biters likely stem from litters where tail biting is common across the litter; thus our findings that biting behaviour is lower in the Free treatment could have benefits for pigs later in life as well.

There were some limitations in recording of piglet behaviour. Occasionally the observer's view was obstructed by the back wall of the pen or by the sow, and during very active periods it was difficult to accurately record all behaviours taking place.

Moreover, it was sometimes difficult to determine exactly which behaviour was being observed, particularly with regard to fighting, play, and social nudging.

3.5.4 Faecal cortisol and hoof scores

Although there was no effect of treatment on faecal cortisol concentrations, there was a tendency for higher cortisol levels during week 1 in piglets from the Free treatment. This time period coincides with when the crate is initially opened. As the samples were taken at pen level, this could be a result of faeces from piglets which may have had a negative interaction with the sow, or even become slightly injured or crushed being included in the sample. However, the lack of a difference in hoof lesions suggests that there were at least no more injuries to the legs due to the movement of the sow. Another hypothesis is that it could also be due to increased activity of piglets in the free lactation pen due to having more space available.

3.5.5 Behaviour post-weaning

In the post-weaning behaviour tests few differences between the treatments were observed; the only effect of lactation treatment was that pigs reared in the Free lactation pens took longer to approach the novel object. Nevertheless, this was only during week one, and by week two there was no difference. Using the same novel object however over all tests may have meant that it lost its novelty, and repeating the tests in the same order, although randomising pen order, may also have resulted in experimental fatigue. Although there was no statistical difference, pigs from the Free treatment also took longer to recover from a startling event, and more pigs in

Free pens startled. Taken together, these data suggest a higher level of caution in Free pigs. Schmitt *et al.* (2019) found that pigs reared in a poor pre-weaning environment (an artificial rearing enclosure from day 7 post farrowing until weaning) performed with less fearfulness in similar post weaning tests. The authors hypothesised that this was due to these animals becoming more habituated to human contact than sow reared piglets, as they had a smaller enclosure and fewer locations to hide. It is possible that there were similar underlying causes in this study. In the Free pens, it is difficult to catch piglets for handling, and as such there is often more of what could be perceived as 'negative' interactions between piglets and humans; as piglets are able to escape into the sow's lying area, removal for procedures such as weighing is often a more prolonged activity which could involve a tendency for chasing of piglets. This could have caused piglets to become more wary of unexpected events. It is important to consider that these results may not be representative of conditions on a commercial pig farm; the study was conducted in a research unit where the pigs were very familiar with human contact.

3.6 Conclusion

Rearing pigs in free lactation pens had positive implications for post weaning performance, with final weight and days to slaughter improved compared with conventional farrowing crates. The performance data suggest that these pigs were better equipped to deal with the stress of weaning, which had a long-lasting positive effect on growth. Pre-weaning damaging behaviour was reduced by the use of free lactation pens which is an important finding as the industry must move towards rearing pigs with intact tails in accordance with European Legislation. Most importantly for both welfare and production, mortality rates were not affected by the use of free lactation pens compared with traditional farrowing crates. Thus, the free lactation crates which were investigated hold potential to ease a transition to a complete removal of crating of sows, as they can minimise losses for producers, and enhance growth, while meeting more of the needs of the animals than traditional crates.

Chapter 4

Discussion and Conclusions

4.1 Discussion

Concerns about animal welfare have meant that farming systems that confine and restrict the sow during gestation have mostly been banned in the EU. Farrowing crates, however, have remained in use as they are presumed to reduce piglet mortality. However, they also present serious animal welfare problems, restricting sow movement and preventing normal pre-farrowing and maternal behaviour. This study has shown that free lactation crates can benefit sow and piglet welfare in some ways.

Sows used the extra space provided and occupied all orientations in the pen. This was hypothesised and it is an important finding as it proves that sows will choose to be more active when allowed more freedom of movement, in farrowing crates the only options for movement are to stand, sit and lie. Sows housed in free lactation pens had the opportunity to move around the pen and they did utilise this extra space. Allowing captive animals greater opportunities to display a broader range of behaviours is generally accepted to improve their welfare. Furthermore, sows in free lactation pens had significantly better locomotion scores at exit from the farrowing room, this is very important for both sow health, welfare and comfort as well as for the longevity and productivity of the sow. Allowing sows to be more active during lactation, therefore, benefits sow locomotory health. Sows in farrowing crates do not have the option to take the few steps in the pen which those in free lactation pens can, and this makes a difference to locomotory health over the period of confinement. Systems which promote better sow health will benefit both the sow and the producer. Sows whose locomotory health is well maintained will have increased longevity and therefore produce more piglets. A reduction in stocking density, increased space allowance during lactation as well as the opportunity to perform more behaviours can improve the welfare of captive animals, this in turn will improve their lifetime performance, longevity and productivity.

Sows in the Free treatment had significantly lower tear stain scores around the left eye at weaning. This indicates a reduced level of stress in Free sows when compared with those housed in farrowing crates over the test period. However, salivary cortisol concentrations were higher in Free treatment sows. While this is a measure of stress it can also reflect higher activity and excitement levels. In this case it is likely that the increase in salivary cortisol concentration reflects the increased activity in sows housed in free lactation pens when compared with those housed in farrowing crates.

Piglets from the free lactation pen treatment also experienced benefits of free lactation pens. With regard to performance there was an improvement in weight gain with Free pigs weighing 114.73kg at finish compared to 110.82kg for Control pigs. There was also a reduction in days to slaughter with free pigs reaching the 105kg target weigh in 147.56 days compared with 149.23 days for Control pigs. This is a very promising result regarding both productivity and welfare, and a result which is likely to appeal to producers. This improvement in production also points to an improvement in welfare suggesting that pigs reared in free lactation pens may experience less stress in the weaner stage, a stage often marked by slowed growth due to reduced feed intake caused by stress.

Piglets tended to perform fewer damaging behaviours (ear and tail biting) during lactation in the Free treatment when compared with Control piglets. Although this result was not significant, it may suggest that Free piglets experience less stress than Control piglets, these damaging behaviours are rarely observed under more natural conditions and are a sign of stress and poor welfare. A reduction in damaging behaviours is very positive and could lead to reduced need for antibiotic use and possibly even tail docking, a very common practice on Irish pig farms which presents its own animal welfare issues.

One of the main aims of this study was to determine whether the use of free lactation pens would affect piglet survival when compared with farrowing crates. Mortality was not significantly affected at 15.95% in Free and 14.42% in Control. This is a very important result, as it shows that farrowing crates are no more effective at preventing piglet mortality. Therefore, alternative systems, such as free lactation pens, which can deliver comparable piglet survival rates while also improving sow freedom of movement and welfare should be implemented on pig farms.

There were limitations to this study and some measurements could be improved upon in further research.

An aspect of sow behaviour which is very important around the time of farrowing, nest building, was not recorded. Knowing whether sows in the Free treatment gained the opportunity for any increase in nest building behaviour as a result of the increased space allowance and freedom of movement would be useful in confirming whether this type of farrowing accommodation offers welfare benefits to the sow. Future studies may focus not only on locomotory behaviours, but on other sow behaviours including nest building and interactions with piglets to gain a more complete picture of the benefits of this type of farrowing accommodation for sows.

With regard to observation of piglet behaviour, pre-weaning it was sometimes difficult to distinguish behaviours, for example playing and fighting. While observers worked collaboratively in an effort to ensure uniform classification of behaviours, a more detailed description in the original ethogram would have been beneficial. Post-weaning behaviour tests, while pen order was randomised, were carried out in the same order, future studies may benefit from randomising test order.

There was a focus on crushing as a cause of piglet mortality in this thesis. This was due to the fact that farrowing crates were originally designed to reduce crushing and producers are weary to move away from this system because of the fear of higher piglet mortality due to crushing. Piglet mortality is multifactorial, with causes of death such as hypothermia and starvation being linked to crushing. However, crushing is the main reason producers are reluctant to move towards loose housing. So while all causes of death were recorded in this study, the focus was on crushing. This study has shown that other causes of mortality may be reduced by the use of free lactation pens, thereby reducing some of the risk associated with lack of confinement of the sow. Future studies may examine the relationships between causes of piglet mortality in loose or temporarily confined farrowing systems.

Changes in pig production are influenced by changes in thinking of consumers and their demands with regard to welfare. Changes in legislation follow to reflect this evolving process. There is currently pressure within the EU for a move away from farrowing crates which restrict the sow severely and impact sow welfare. The key to good welfare is health and the ability to express natural behaviours. Animals are motivated to express specific behaviours and frustrating this internal drive negatively affects the welfare of captive animals. This can lead to stress for pigs in the farm environment. Such stress can negatively impact health and welfare. This in turn reduces production. Therefore, ensuring good welfare is of benefit for both animals and producers. It is important for both policy makers and producers that the cost implications of potential changes are first identified. However, from these results alone there is already quite a strong argument for the use of free lactation pens. Regarding sow locomotory health and piglet growth there are benefits for both pig welfare and production.

In intensive pig production the use of farrowing crates is almost exclusive with almost all sows kept confined in farrowing crates during the entire farrowing and lactation period (Damm, 2008). The free lactation pen is a practical solution to solving the problem of farrowing crates on Irish farms and more attractive to farmers than a move toward loose housing. By using temporary confinement, the welfare interests of the sow and piglets are both prioritised. There may be a compromise with regard to sow numbers as the free lactation pens used in this study were slightly larger than the control pens. However, this may not necessarily impact production negatively as Free pigs grew to a heavier weight in a shorter time than those from the Control treatment. Therefore, it may be possible for producers to maintain their current level of output with slightly fewer sows. The slight reduction in stocking density may also benefit both the animals and producers, leading to increased space allowance which can positively affect welfare.

4.2 Conclusion

The primary objective of this study was to investigate the effects of free lactation crates on sow and piglet welfare when compared with conventional farrowing crates. The results suggest that the use of this type of crate which allows for temporary confinement of the sow can have positive effects on both sow and piglet welfare. Use of free lactation pens is beneficial for sow welfare, allowing more freedom of movement and permitting sows to perform a wider range of behaviours. There are also benefits to piglet welfare as they can interact more with the sow and have better access to the udder for feeding resulting in increased growth. The use of free lactation pens could contribute to a more positive image for the Irish pig production industry, something that is becoming ever more important as consumers are more aware of animal welfare issues in food production. However, more detailed investigations to ensure piglet survival pre-weaning are necessary before this type of farrowing management is implemented. This is a complex problem, with other factors which must be considered including sow characteristics for example which play a very important role in piglet survival. So, while introducing greater freedom of movement for the sow and encouraging a wider range of maternal behaviours may be beneficial for both the sow and her piglets, it is also crucial to ensure sows are selected for maternal behaviour as this is a vital for piglet survival. Changes to the current system must not only be beneficial to both the animals and producers but also must be manageable for producers to implement, a switch to free lactation pens may be feasible on Irish pig farms, and may have positive effects for the health and welfare of commercially farmed pigs in Ireland.

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